A Pocket Particle Accelerator | Cooling Zones for Fish

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ NOVEMBER 18, 2023

The Ongoing Toll of a Disaster

Flint grapples with the mental health impact of the water crisis

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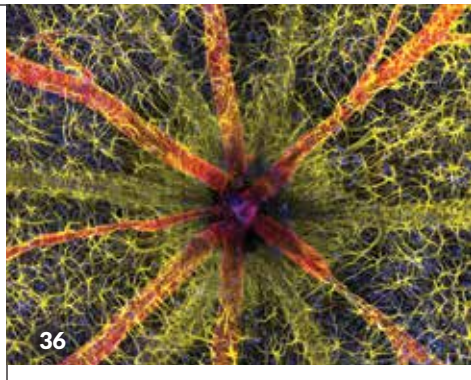
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COVER At Flint City Hall in 2015, residents call for access to clean water. *Christian Randolph/The Flint Journal-MLive.com/Associated Press*

FROM TOP: K. BOURZAC; H. QAMBARI AND JAYDEN DICKSON; B.A. GÜELL

Scientific meetings — it's nice to see you again

Coverage of scientific meetings has always been one of the pillars of *Science News*' journalism. From the early days, our reporters showed up in person to get stories that no one else had. In the 1920s, Jane Stafford regularly reported from medical meetings, covering topics from the common cold to cancer. In 1981, Julie Miller, life sciences reporter at the time, attended a meeting where medical researchers were discussing the first cases of acquired immunodeficiency syndrome, or AIDS. She came back knowing she had to write about it (*SN: 11/14/81, p. 309*). And Ivars Peterson, who covered physical sciences, math and technology, was introduced to a Web browser at a physics meeting in the 1990s.

The COVID-19 pandemic interrupted a lot of our face time with scientists. Virtual gatherings were no doubt necessary to keep people safe, but they just weren't the same. "Going to meetings gives you a main line to the science," says staff writer Meghan Rosen, who recently attended a meeting of the American Academy of Pediatrics in Washington, D.C. "You get to immerse yourself in different subjects in a way that's completely different from reading a paper."

One of the perks is finding stories that wouldn't necessarily make it into the journals. In 2018, physics and senior writer Emily Conover wrote an award-winning story about how ravens were to blame for a glitch in the gravitational wave detector LIGO — she got the tip at a meeting of the American Physical Society in Columbus, Ohio. In 2020, neuroscience and senior writer Laura Sanders attended the American Association for the Advancement of Science meeting, held in Seattle that year. During an interview with a researcher about an entirely different topic, Sanders was tipped off to a project about improving the ability to record brain activity in people with curly, coarse hair (*SN: 4/11/20, p. 5*).

I'm happy to report that we are back to covering scientific meetings in person. Staff writer Nikk Ogasa went to Pittsburgh for the Geological Society of America meeting; you can read his story about how pumping cold water into rivers could serve as "air conditioning" for fish (Page 9). Earth and climate writer Carolyn Gramling was in Cincinnati for the Society of Vertebrate Paleontology meeting, where she was reminded of the value of chatting with researchers just after their talks. Like Rosen, Aimee Cunningham also attended the American Academy of Pediatrics meeting. Intern Saima S. Iqbal went to the American Society of Human Genetics meeting in Washington, D.C., alongside molecular biology and senior writer Tina Hesman Saey.

And early in October, seven *Science News* writers and editors, including myself, went to ScienceWriters 2023 in Boulder, Colo. We discussed issues in journalism, learned how to be better at our craft and attended scientific sessions. I heard researchers talk about the sun's corona and solar wind, the world's most advanced atomic clocks, air quality following the nearby Marshall Fire in 2021 and more. I met up with staffers who work remotely, with former interns and with some of our freelance writers whom I'd never seen in person before.

Judging by the energy and enthusiasm at the meeting, I'm not the only one who was glad to be back. I look forward to attending more meetings — though don't be surprised if I'm still wearing my mask. — *Elizabeth Quill, Executive Editor*

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50 YEARS AGO

Putting smell in the whiffer

P.P.C. Graziadei and J.F. Metcalf of Florida State University have been producing…ever more detailed, evidence for olfactory nerve regeneration in mammals…. Might olfactory nerves be regenerated in people who have trouble smelling, thereby restoring or improving their sense of smell? "The phenomena of regeneration are applicable to all vertebrates and most likely to humans," says Graziadei.

UPDATE: The scientists' hunch was right on the nose: The human cells that detect scent information and send it to the brain can replenish themselves, though exactly how is unclear. Experimental therapies to help people who have lost their sense of smell due to COVID-19 could help researchers figure it out (*SN: 9/24/22, p. 14*). Smell training, which involves regularly and deeply smelling various scents, might rewire cells' connections to the brain or stimulate new cell growth. Treating damaged cells with steroids and blood plasma might aid healing. More invasive treatments such as nasal lining transplants aim to boost regenerative stem cells.

The Large Magellanic Cloud (center) and Small Magellanic Cloud (right) shine bright above the Paranal Observatory in Chile. Some astronomers are campaigning to rename those galaxies.

YURI BELETSKY/LCO, ESO

SOAPBOX

Scientists call for renaming the Magellanic Clouds

Names have significance, especially when they're written in the stars.

A group of astronomers is coalescing around an idea to rename two neighbors of the Milky Way, the Large and Small Magellanic Clouds.

Named after explorer Ferdinand Magellan, the satellite galaxies are visible to the naked eye from the Southern Hemisphere. But Magellan's name is not fitting, astronomer Mia de los Reyes and colleagues argue. The leader of the first expedition to successfully circle the globe, Magellan enslaved and killed Indigenous people encountered on the voyage, which set out from Spain in 1519.

"Because we're naming things in the night sky, which belongs to everyone, we think that it's important to have names that reflect all of humanity," says de los Reyes, of Amherst College in Massachusetts. She calls for the name change in an opinion piece published September 12 in *Physics*. Magellan's voyage helped pave the way for Spanish colonialism in South America, Guam and the Philippines, says de los Reyes, who is Filipino American. "Many people see Magellan as a villain in the Philippines."

The Magellanic Clouds loom large in the field of astronomy. They're independent galaxies, but close enough that astronomers can observe the individual stars within. "The Magellanic Clouds are this amazing laboratory for seeing things up close and personal," says Sally Oey, an astronomer at the University of Michigan in Ann Arbor who supports the name change.

Magellan wasn't an astronomer. The clouds were noted by a member of his expedition, but they were already well-known to many cultures in the Southern Hemisphere, and even to previous European explorers. "It doesn't make sense to have them named after any one person, let alone a person who never actually studied them," says astronomer Gurtina Besla of the University of Arizona in Tucson.

The galaxies have been known scientifically by Magellan's name since only the end of the 19th century—well after Magellan's voyage. That's just a blip in the history of astronomy, the scientists argue.

Over 100 astronomers have expressed interest in the campaign, anchored by a core group of about 50, de los Reyes says. The group aims to bring the proposal to the International Astronomical Union and eventually hold a vote on the name change. Other fields of science are undergoing similar debates. For example, groups of researchers are pushing to revise offensive names for certain plants and animals (*SN: 9/25/21, p. 12*).

The astronomers are now trying out new names. One popular suggestion is the "Milky Clouds." That would maintain the acronyms LMC and SMC. And it would reflect the galaxies' connection to something much bigger than any one person—the Milky Way. —*Emily Conover*

SAY WHAT?

Gerozyme \jeh-roh-zime\ n.

An enzyme associated with aging in animals

People's muscles tend to dwindle and weaken with age, especially with lack of use. Continued muscle loss makes daily tasks harder to do and increases the risk of falling. Researchers are teasing apart what's behind this muscle loss by focusing on an aging-related enzyme, what they've named a "gerozyme."

The enzyme, called 15-PGDH, breaks down a signaling compound that helps regenerate damaged muscles. Stem cell biologist Helen Blau of Stanford University School of Medicine and colleagues previously found that blocking 15-PGDH in old mice restored withered muscles and improved strength after a month of treatment.

Blau's team has now found that 15-PGDH accumulates in the muscles of old mice as connections that let muscles and nerves communicate are lost, another consequence of aging. Treating old mice for a month with a drug that inhibits 15-PGDH restored the connections and boosted the animals' strength, the team reports in the Oct. 11 *Science Translational Medicine*. This suggests 15-PGDH might be a target to help recover strength lost to nerve injuries or aging in people. —*Aimee Cunningham*

FIRST

Cave lions were fair game for Neandertals

Roughly 48,000 years ago, Neandertals killed a cave lion by thrusting a wooden spear into its abdomen, lion remains from Germany suggest. The discovery represents the first direct evidence of Neandertals hunting cave lions, and the oldest evidence of any hominid slaying a large predator, say zooarchaeologist Gabriele Russo of the University of Tübingen in Germany and colleagues. But such behavior probably began much earlier among Neandertals, the team reports October 12 in *Scientific Reports*.

The researchers also examined three cave lion paw bones from another German site that date to at least roughly 190,000 years ago. These bones, discovered in 2019, belonged to a cave lion (*Panthera spelaea*) that Neandertals skinned for its pelt, the team suspects. The bones lay close together and include one with marks typically made during skinning of animal hides. No evidence indicates that the paw bones were used as pendants or as parts of clothing.

The team's analysis of a cave lion skeleton, which was unearthed in 1985, revealed a puncture wound on a rib that resembles impact marks made by wooden spears. The wound's angle suggests that hunters approached the lion from behind and stabbed it in the lower abdomen while it lay on its right side. Stone-tool marks on other bones indicate that hunters butchered the animal. Previous finds have suggested Neandertals used wooden spears to hunt wild horses 300,000 to 400,000 years ago, and to hunt deer and elephants roughly 125,000 years ago (*SN*: 3/25/23, p. 16). —*Bruce Bower*

A punctured rib bone in this cave lion skeleton indicates that Neandertals killed the big cat with a wooden spear (replica shown).

By analyzing the guts of periodical cicadas, researchers have finally confirmed that the insects do in fact feed during adulthood.

RETHINK

Cicadas' guts help bust a long-standing myth

There are at least three certainties in life: death, taxes and the periodic emergence of cicadas. But one big cicada uncertainty has finally been put to rest—whether the adult insects eat.

Periodical cicadas (*Magicicada* spp.) live in broods across the eastern United States. Every 13 or 17 years, depending on the brood, they emerge from the ground en masse to mate and lay eggs on trees for a month or so before dying. Their babies hatch, fall to the ground and burrow into the earth, feeding on plant roots until the next emergence. But there's long been a popularly accepted idea that periodical cicadas stop eating once they emerge.

The perception might stem from the adults' lack of chewing mouthparts, says entomologist James Hepler of the U.S. Arid Land Agricultural Research Center in Maricopa, Ariz. But scientists have reported seeing adults stick their tubular mouthparts into plant stems, possibly to access sap.

Hepler and colleagues examined the gut contents of 75 cicadas from Brood X (*SN*: 12/18/21 & 1/1/22, p. 24). The analysis turned up DNA from 22 kinds of plants, including box elder, ash, oak and cannabis, the team reports October 18 in the *Journal of Insect Science*.

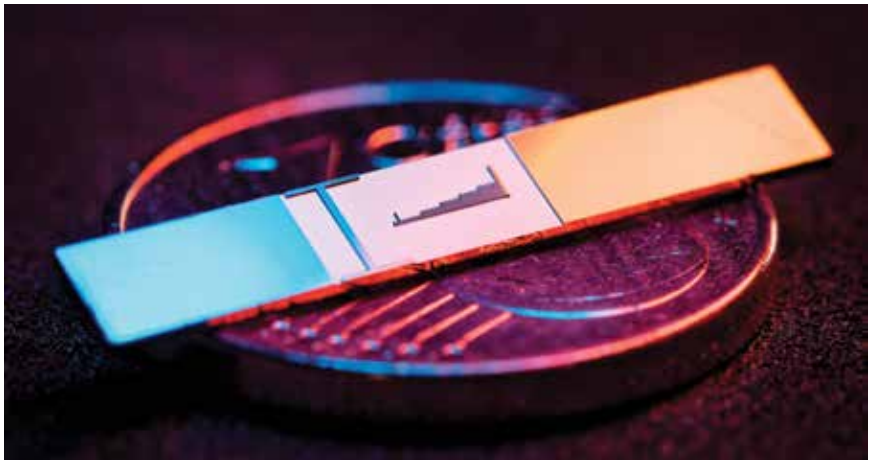
"It's really nice that they actually looked at the gut content," says evolutionary biologist Chris Simon of the University of Connecticut in Storrs. The finding verifies that adult cicadas ingest these particular plants. —*Darren Incorvaia*

FROM TOP: SARAH ROSS/ISTOCK/GETTY IMAGES PLUS; VOLKER MINKUS, ©NLD

PHYSICS

Tiny chips get electrons up to speed

The laser-powered accelerators could find uses in medicine



When hit with laser light, particle accelerators on a chip (shown on a 1¢ euro coin) give electrons passing through an energy boost. Such chips could be used in science and medicine.

BY EMILY CONOVER

One day, powerful particle accelerators might fit in your pocket.

Two teams of researchers have built tiny structures that both accelerate electrons and keep them confined in a manageable beam, instead of spewing them willy-nilly. That's a first for such mini accelerators, and a crucial step toward making these devices more useful and widespread.

"One of the main problems with particle accelerators … is that they're too big and they're too expensive," says physicist Jared Maxson of Cornell University, who was not involved with the new research. Miniaturizing the devices means scientists could make high-energy electrons on a tabletop, Maxson says. That could open up new possibilities for medicine and science.

Constructed on silicon chips, the accelerators are composed of two rows of about 2-micrometer-tall pillars, reminiscent of miniature rows of skyscrapers. When hit with laser light, the pillar structure generates electromagnetic fields that push the subatomic particles faster and faster along an extremely narrow alley between the pillars, less than a micrometer wide.

Electrons in one device gained 12.3 kiloelectron volts of energy over a distance of half a millimeter, a 43 percent bump that brought the particles to 40.7 kiloelectron volts, physicist Peter Hommelhoff and colleagues report in the Oct. 19 *Nature*.

Meanwhile, carefully placed gaps between the pillars help keep the beam of electrons in focus, mimicking the capabilities of larger accelerators. "This is really the first accelerator based on nanophotonics that contains all the features any modern accelerator contains," says Hommelhoff, of the University of Erlangen-Nuremberg in Germany.

Stanford University physicist Robert Byer and colleagues reported a similar achievement in a paper posted October 4 at arXiv.org, with energy gains up to 23.7 kiloelectron volts. The two groups are part of a larger collaboration called the Accelerator on a Chip International Program, or ACHIP, which unifies efforts to build these small accelerators.

The world's most powerful particle accelerator is the Large Hadron Collider, or LHC, near Geneva. With a ring that's a whopping 27 kilometers around, the LHC accelerates protons to energies of trillions of electron volts. The new tiny accelerators, with mere thousands of electron volts, won't be creating a Higgs boson—the particle famously found at the LHC in 2012 (SN: 7/2/22, *p.* 18)—anytime soon. But such devices have their own set of potential applications.

For example, high-energy electrons can treat skin cancer by damaging DNA within cancer cells, killing them. But generating those energetic electrons currently requires a roomful of bulky machinery. With an accelerator on a chip, electron beam therapy could become more accessible.

And similar treatments could go more than skin-deep. "The dream is to be able to have a fiber that can go in a human body to do a local radiation treatment … because the whole accelerator can fit inside you," says Pietro Musumeci of UCLA, who is a member of ACHIP but was not involved with the new results.

Another application could involve using the devices to create special states of light that could be useful for quantum computing. Or the accelerators might be useful for materials research, such as making images of thin materials with ultrahigh time resolution, for example.

But the accelerators still have a long way to go. Electrons emerge from the devices at a rate that's many orders of magnitude below conventional accelerators. And while the devices focus the beam in two dimensions (in the direction of the beam and perpendicular to it horizontally), further work is needed to focus the beam vertically.

The devices' energy gains need to be scaled up too. The energy the electrons accumulate over a given acceleration distance is on par with conventional accelerators, tens of millions of electron volts per meter. But scientists want to far surpass those accelerators with billions of electron volts per meter.

Even so, the work demonstrates techniques that once seemed absurd to attempt. At first, when Byer described the idea to colleagues, "they'd all break out in hilarious laughter," he says. "We don't get laughter anymore; we now get appreciation." ■

STEFANIE KRAUS AND JULIAN LITZEL/LASERPHYSICS/FAU

PLANETARY SCIENCE

Exoplanet collision left infrared clues

A distant star's odd behavior hints at mutual obliteration

BY ELISE CUTTS

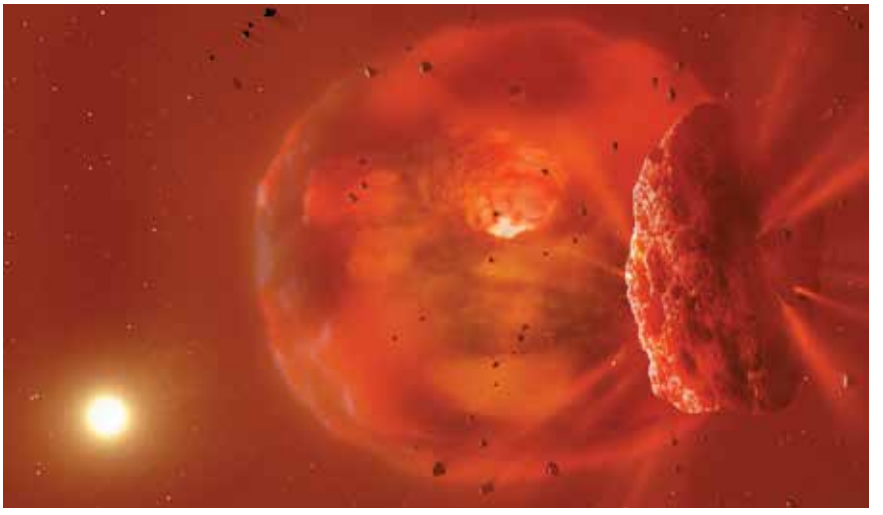
In a solar system about 1,800 light-years from Earth, two planets smacked into one another in an impact that vaporized them both. Astronomers may have caught them in the act.

An incandescent blob of leftover planet, lingering after an impact, could explain a surge of infrared light from a remote star, researchers report in the Oct. 12 *Nature*. And the ensuing debris field could explain a subsequent dimming of the star, the team says. While scientists have glimpsed planetary debris in other solar systems before, no one has seen the smoldering remains of a collision between exoplanets perhaps until now (SN: 6/17/23, p. 32).

"The possible detection of a postimpact body is really exciting," says astrophysicist Philip Carter of the University of Bristol in England. "As far as I'm aware, no one's claimed this before."

Detecting the aftermath of this cosmic smackdown involved more than a little luck. Astronomer Matthew Kenworthy of Leiden Observatory in the Netherlands had been looking for rings around exoplanets, he says. So he was scouring telescope data for stars that flicker or dim in unusual ways. When the All-Sky Automated Survey for Supernovae — an ongoing project to monitor the entire sky for exploding stars — captured the sunlike star ASASSN-21qj repeatedly dimming in visible light, "I immediately jumped on it," Kenworthy says.

As Kenworthy analyzed the fading star, he posted about its unusual behavior on social media. His posts caught the eye of citizen scientist Arttu Sainio, who pointed out that the star had brightened in infrared about 900 days before it dimmed in visible light, according to data from NASA's WISE telescope. That dashed Kenworthy's hopes for rings. But maybe he had found something else just as fascinating.



The collision of two exoplanets may have left behind a doughnut-shaped cloud (illustrated) of vaporized rock and other debris, which cast an infrared glow visible to NASA's WISE telescope.

MARK GARLICK

Kenworthy and colleagues realized that an impact could explain the glow and the dimming that followed more than two years later. Calculations suggest that two Neptune-like planets colliding could explain the light. The planets would have vaporized, forming a doughnut-shaped body of hot, rocky material that cast an infrared glow. The star later dimmed when impact debris smeared out around it, blocking some of its visible light.

Alternatively, astronomers could have observed two separate events: an infrared glow from starlight-warmed dust, perhaps from a collision of protoplanets, followed by dimming as unrelated material passed by the star. But two rare events happening in close succession is "really, really, really unlikely," Kenworthy says.

The blob and debris could coalesce into a planet and moons. How long that might take, whether a few years or several thousand, isn't clear, Carter says. Either way, observing the star will give scientists a rare chance to witness, not just simulate, what happens after planets collide. ■

NEWS IN BRIEF

Quantum squeezing broadens LIGO's horizons

Putting the squeeze on light improves gravitational wave observatories. An upgrade to the U.S. observatory LIGO exploits a quantum rule to make it easier to spot spacetime ripples that arise from violent cosmic events. LIGO should detect up to 65 percent more collisions between massive objects like black holes than without the upgrade, researchers report October 30 in *Physical Review X*.

To detect gravitational waves, LIGO uses laser light frequency to measure minute changes in distance between mirrors placed far apart. The Heisenberg uncertainty principle says you can measure frequency very well if you don't care about uncertainty in the amplitude, a key to finessing LIGO's detecting abilities.

Previously, scientists used a technique called quantum squeezing to reduce uncertainty in the laser's frequency, letting LIGO turn up the power to see more distant events. But further efforts in this direction would have boosted amplitude uncertainty at lower laser frequencies, which can jostle LIGO's mirrors and stifle the benefits of more power. The upgrade suppresses frequency uncertainty at higher laser frequencies and amplitude uncertainty at lower ones to increase detections. Heavier mirrors in future machines could also boost detections. "The beauty is you can do both," says MIT physicist Lisa Barsotti. — *James R. Riordon*

Gliding tree frogs (shown), European common frogs and some other species mate in tangled balls. Females can survive the mobbing by faking their own deaths, rotating their bodies and imitating male calls.

ANIMALS

How frogs survive dodgy mating balls

Females play dead and more to escape overbearing males

BY SUSAN MILIUS

Grab fast and hang on for hours. A fierce grip is all the courtship finesse a male frog needs in species that reproduce in frenzied mobs. Female European common frogs, however, have at least three moves that help them escape, scientists report October 11 in *Royal Society Open Science*.

With hundreds of *Rana temporaria* frogs gathering at a natural pool, mating "can look quite like a mess," says evolutionary behavioral ecologist Carolin Dittrich of the University of Veterinary Medicine Vienna. And dangerous. Females can drown.

Several males clamp onto the same female, creating a tight tangle called a mating ball. Males hold tight and squirm for a good position for releasing sperm onto eggs put into the water by females. *R. temporaria* mating balls typically last for several hours but can persist for two days.

Dittrich started wondering about female defenses while reviewing video of *R. temporaria* frogs mating in the lab. She had left the room during filming so as not to disturb the frogs. As she analyzed the footage, she saw a large female apparently die in a male's embrace. The female's legs stretched out in dead-frog abandon. The male let go and pursued another female.

After about two minutes, the "dead" female started moving again. Looking dead could let a female escape a male's unwanted grasp, propose Dittrich and Mark-Oliver Rödel, curator of herpetology at the Berlin Natural History Museum.

Intentionally playing dead would be hard to prove in frog scrambles, says wildlife ecologist Brandon Güell of Florida International University in Miami. When female frogs go limp, "sometimes that's the first step of drowning and dying because they're probably exhausted," he says.

In Dittrich's recordings, 25 of 54 females that were grabbed by a male broke his grip. Going limp was not the only move that looked like resistance. Females often combined several in possible escape attempts.

The most common maneuver involved females rotating around the long axis of their body, angling somewhere between a log roll and a ballerina twirl. Males moved their legs to counteract the spin but on occasion lost their grip.

Females also grunted, in what could sound like the "release call" that males make when other males mistakenly embrace them while mating. The female grunts may be a form of male impersonation, the researchers suggest.

Güell has heard gliding tree frog (*Agalychnis spurrelli*) females make guy-like sounds when grabbed. The female "Let go!" might be common among frogs that mate in grabfests, he says. "It's not commonly heard; it's not commonly recorded … and published."

Female resistance in *R. temporaria* hasn't gotten much mention in the modern literature, Dittrich notes. Besides one paper from the 20th century, she had to go back to the 18th century to find discussion of female resistance to male power. ■

ANIMALS

Menopause affects wild chimps too

The evolutionary benefit of living past reproductive years is unclear

BY BRUCE BOWER

Female chimps living in an East African forest experience menopause and then survive years, even decades, after becoming biologically unable to reproduce.

The apes are the first known examples of wild, nonhuman primates to go through the fertility-squelching hormonal changes and live well beyond their reproductive years. The finding raises new questions about how menopause evolved, UCLA evolutionary anthropologist Brian Wood and colleagues conclude in the Oct. 27 *Science*.

Until now, females who experience menopause and keep living for years have been documented only in humans and five whale species. The evolutionary benefit to explain such longevity past the point of being able to pass on genes is unclear.

Although evolutionary explanations for menopause remain debatable, the new finding reflects an especially close genetic relationship between humans and chimps, Wood says. "Both are more predisposed to post-reproductive survival than other great apes."

Some evidence suggests that female fertility ends at similar ages in humans and chimps (*Pan troglodytes*) if our ape relatives live long enough, says Kristen Hawkes, an anthropologist at the University of Utah in Salt Lake City. But in other studies, female chimps, such as those studied by Jane Goodall at Tanzania's Gombe National Park, age quickly and often die in their early 30s, usually while still having menstrual cycles, she says.

In Wood and colleagues' study, "what's surprising is so many females living so long after menopause," Hawkes says.

The researchers examined mortality and fertility rates of 185 females in the Ngogo community of wild chimps in Kibale National Park in Uganda from 1995 through 2016. By first assessing chimps

B.A. GÜELL

when they were young or middle-aged, the team was able to get an accurate read on the animals' ages.

Hormonal measures of fertility declined after age 30, and the team observed no births in chimps older than 50. Sixteen females lived past age 50, some into their 60s. Urine samples taken from 66 females, ages 14 to 67, provided hormonal evidence of fertility declines. Menopause also results in an end to women's reproduction at about age 50, Wood says.

On average, females in the Ngogo community live 20 percent of their adult years—defined as starting at age 14—after having lost the ability to reproduce, the scientists estimate.

Wild chimps' social lives do not fit a scenario, previously suggested by Hawkes and others, for the evolution of human menopause. Women, the idea goes, may live so long past their reproductive years because grandmothers provide vital care to their grandchildren. But female chimps move to new communities during adolescence, when they reach physical maturity. Grandmothers usually have no breeding daughters nearby whom they can assist.

Another possibility is that older female chimps possess experience and knowledge necessary for group survival. Or perhaps an absence of predators due to human hunting, plentiful food sources and successful competition with nearby chimp groups supported a temporary emergence of long life spans among Ngogo females. Similarly, female survival long beyond the reproductive years also occurs in captive chimps.

Ngogo chimps inhabit a forest that has been protected from logging and exposure to deadly infections carried by humans, perhaps aiding longevity in male and female chimps, the team says. Males in the group live about as long as females do. Menopause may have evolved in chimps living in relatively undisturbed settings due to young females migrating to new groups.

After these moves, aging females having kids become increasingly related to other group members and their offspring. At advanced ages, females with local kin—in chimp groups and perhaps ancient human groups—evolved to stop reproducing so young females with fresh genes could conceive new generations, the team suggests.

Evolutionary biologist Susan Alberts of Duke University doubts that females in a slow-reproducing species become related to enough individuals in a new group for that evolutionary scenario to have played out. Instead, "menopause may be a latent trait in primates that gets revealed as mortality rates decline," she says.

Few wild chimp communities have been studied as thoroughly as the Ngogo crowd, making the findings tough to generalize. "We still don't know much about most chimps' lives," Alberts says. ■

ANIMALS

'Air conditioning' helps fish stay cool

Salmon escape the heat in artificial plumes of cold water

BY NIKK OGASA

PITTSBURGH — Salmon may now have their own version of air conditioning.

Last summer, hundreds of fish in the Wrights River in Nova Scotia, Canada, found reprieve from the heat in human-generated plumes of cold water, civil engineer Kathryn Smith reported October 17 at a meeting of the Geological Society of America. Though only proof of concept, the work could aid efforts to conserve cold-water species amid widespread warming due to climate change (*SN: 11/19/22, p. 9*).

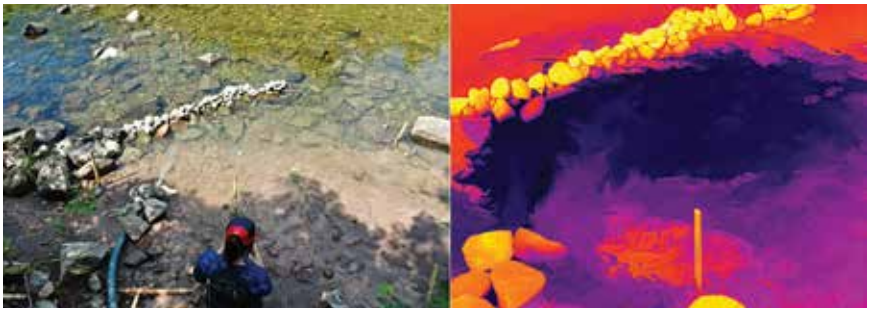
When water temperatures get too high, fish can become stressed and die. In rivers, Atlantic salmon and other species sometimes escape the heat by flocking to cooler areas near groundwater springs and tributaries.

A lot of work has been done to preserve these naturally occurring refuges, "but there hasn't really been an emphasis or focus on if we can create cold-water habitat," said Smith, of Dalhousie University in Halifax, Canada. So she and colleagues pumped groundwater that was about 9° Celsius (about 48° Fahrenheit) from a nearby well into the river, manifesting a plume that could be as much as 21 degrees cooler than the surrounding water.

The plume attracted several hundred fish of various species, including Atlantic salmon and brown trout. Most were juveniles. But when a heat wave brought on maximum water temperatures of about 30° C, adults also took shelter.

For a pump-free approach, the team rerouted river water into an underground trench, where it cooled before re-entering the river. This method lowered the water temperature by just a few degrees, but the team still observed fish frequenting the cooled flow throughout the summer.

Determining how many sites would need to be built to substantially benefit fish populations and how to sustain them while keeping energy costs low will require more work, says John Ackerman, a consulting engineer based in Hazleton, Pa. But, he says, "the concept is solid." ■



K. SMITH

Last summer, researchers pumped groundwater into Canada's Wrights River (left) to create a cold plume that fish could shelter in. A thermal image (right) shows the effect: The cold plume appears purple while warmer river water and sun-baked rocks appear orange and yellow.

Staghorn corals (*Acropora cervicornis*) grow at Florida's Mote Marine Laboratory. Scientists at Mote and around the world are experimenting with new techniques to restore reefs.

ANIMALS

3 innovative ways to save coral reefs

Scientists add an array of new tools to their coral survival kits

BY DARREN INCORVAIA

Erinn Muller should have reason to despair. The marine biologist studies coral health in Florida, a state whose reefs have been devastated by extreme heat, increasingly ferocious hurricanes and deadly infectious diseases (*SN: 8/3/19, p. 14*).

"We've lost 98 percent of our living coral cover," says Muller, of the Mote Marine Laboratory in Sarasota, Fla. While among the hardest hit, Florida's corals aren't alone. From Australia's Great Barrier Reef to the Caribbean, coral reefs globally are in trouble.

But innovative efforts to protect and restore coral reefs buoy the hopes of Muller and other marine biologists. One such effort is Mote's Caribbean king crab nursery, a project of reef-restoration expert Jason Spadaro. There, tiny crustaceans grow into salad-loving foragers. Once they are set loose on nearby reefs, *Maguimithrax spinosissimus* eat away seaweed that's suffocating the coral.

"I'm optimistic because there is really truly so much work being done" to restore coral reefs, says Tali Vardi, a marine biologist and the executive director of the Coral Restoration Consortium, a global community of scientists, managers and restoration experts. While safeguarding the future of coral reefs ultimately depends on halting climate change, "we're trying to maintain pockets of biodiversity" that can serve as a springboard for the long-term recovery of reefs, Vardi says.

Given how diverse coral reefs are, she says, researchers need a diversity of solutions to match. "There's no silver bullet here."

Around the globe, coral biologists are trying everything from low-tech seaweed removal to high-tech artificial fog production to protect corals. Here's a closer look at three of these projects.

Weeding seabeds

In the Great Barrier Reef, it's not crabs doing the weeding. It's volunteers with the international nonprofit Earthwatch Institute snorkeling and diving underwater to pluck macroalgae, the weed of coral reefs. The goal is to free parts of the reef from a seaweed scourge to see if that helps the corals flourish.

"There's been this issue with increases in macroalgae versus corals for a long time," says David Bourne, a marine biologist at James Cook University in Townsville, Australia. If something is out of whack with the reef ecosystem, he says, "the corals lose out and the macroalgae take over."

Though they seem like a cross between plants and rocks, the hard corals that form reefs are actually giant colonies of tiny animals called coral polyps. Each polyp secretes calcium carbonate to form a hard skeleton. And skeleton by skeleton, the polyps build an undersea city. Microscopic algae living inside the polyps give the corals their brilliant colors and generate energy for their hosts via photosynthesis.

Seaweed, however, takes up space and soaks up light that could otherwise be used by corals' algal pals. If coral populations shrink due to stressors like heat or disease, seaweed can quickly proliferate and take their place.

Bourne wanted to know whether the Earthwatch Institute's seaweed-removal program was effective. From 2018 to 2021, volunteers pruned seaweed from 12 sections of the reef — each 5 meters by 5 meters — several times per year, while leaving other seaweed-laden areas

MOTE MARINE LABORATORY

alone. In total, they removed a whopping 2,148 kilograms of seaweed, roughly the weight of an adult rhinoceros.

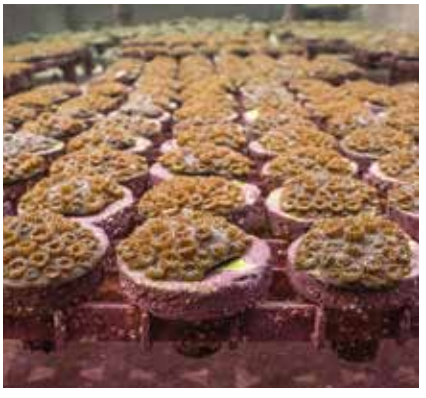
Initially, the tended plots all together had enough corals to cover only about 34 square meters on average. Removing seaweed from those plots led to an average gain of nearly 203 square meters, enough to blanket a tennis court, Bourne and colleagues reported September 13 in the *Journal of Applied Ecology*. This change was not observed in 12 unpruned plots.

"It's not surprising that we saw some recovery," Bourne says. "What was surprising was the amount of recovery and how quickly it happened." Sea-weeding is a straightforward way to restore the reef's competitive balance and help corals thrive, he says.

Bourne hopes the simplicity of the approach will help it spread. "The advantage of sea-weeding is it's really low-tech; anybody can do it," he says. Plus, seaweed tends to be an issue on reefs that are close to shore and known to local communities, "so there's active groups that are interested in helping."

'Reskinning' coral skeletons

Though it may sound macabre, the calcium carbonate skeletons of dead reefs can serve as vital scaffolding for coral transplants. "Reskinning" a dead reef takes advantage of coral microfragments, thin skeletal layers topped with small bits of living coral tissue. Growing microfragments in the lab and then transplanting them onto reef skeletons can, in a way, bring a dead ecosystem back to life.



MOTE MARINE LABORATORY

Fragments of mountainous star coral grow at a land-based nursery in Summerland Key, Fla. Fragments placed on the skeleton of a dead coral will quickly grow and merge together, forming a "skin" on the skeleton.

David Vaughan discovered the restorative potential of coral microfragments through what he calls a "eureka mistake." Vaughan, formerly executive director of Mote and now head of the nonprofit Plant A Million Corals in Summerland Key, Fla., accidentally broke off shards of a branching coral while moving it to a new tank. Some coral polyps remained on the bottom of the tank. Vaughan assumed the tiny animals wouldn't survive. But when he checked on them about two weeks later, he saw instead that they had quickly grown and multiplied.

Large corals grow slowly, Muller says, because they have to put a lot of energy into creating their large calcium carbonate skeleton. Microfragments affixed near each other on a hard surface grow rapidly and fuse together. Mote scientists hacked into the fundamental biology of a slow-growing species to encourage them to direct resources into creating tissue faster, Muller says.

A 2018 study found that microfragments of the mountainous star coral (*Orbicella faveolata*) grew 10 times as much tissue over a 31-month period as larger fragments that were previously used for reef restoration. For every square centimeter of coral that was planted at the beginning of the experiment, microfragments grew an average of 3.38 square centimeters of new tissue, while larger fragments grew only 0.35 square centimeters.

Plantings of coral microfragments off the Florida coast have since withstood disease, bleaching events and hurricanes, and grown large enough to reproduce within several years. Larger transplants typically take a decade or longer to reproduce.

"Spawning after five years," Spadaro says, "was definitely a game changer in terms of restoration." Reskinning with microfragments can produce functional reef ecosystems in a fraction of the time as previous methods. Mote scientists have shared their knowledge with others working to restore corals around the world, including in Hawaii and the Caribbean.

Making shade

Bleaching is the dramatic outcome of great hardship; pushed to the brink by extreme stress, a strained coral belches out its symbiotic photosynthetic algae, turning stark white and losing its primary food source. Excessive heat is the most common culprit, but it's not the only one.

Excess light can contribute to bleaching, too, says biologist Peter Butcherine, of Southern Cross University in Coffs Harbour, Australia. Too much light during algal photosynthesis results in an overabundance of toxic oxygen-containing molecules that are highly reactive and can kill coral cells.

Protecting corals from too much sun exposure can help prevent bleaching, but "you can't roll out thousands of square meters of shade cloth" to shield an area the size of the Great Barrier Reef, Butcherine says.

Instead, Butcherine and others have turned to a more ephemeral approach: creating fog. "It's essentially a sea mist," Butcherine says. Though misting the entire Great Barrier Reef isn't feasible, marine fog could protect sensitive parts of the reef when sunlight is harshest.

In a lab study, shading corals for just four hours a day over about a month could delay bleaching even when water temperatures are high, such that corals could withstand three extra weeks of bleaching-level heat, Butcherine and colleagues reported in the Sept. 20 *Frontiers in Marine Science*. This delay could help corals hold on to their algal partners until the surrounding water temperature decreases.

Researchers are still developing marine fogging and proceeding with caution due to the potential for unintended environmental effects, Butcherine says. The approach currently requires large arrays of misters mounted to ships, which means it is quite expensive to implement, especially on a wide scale.

Butcherine is excited by the potential of using solar-powered drones mounted with misters to deploy marine fogging at reefs around the world. "I'm optimistic that we can make a difference," he says. ■

ANIMALS

Llamas spruce up glacier-free land

Benefits to soil and plants may soften climate change impacts

BY SAIMA S. IQBAL

Within just three years, grazing llamas in Peru's Cordillera Blanca mountains improved soil quality and introduced new types of plants to land exposed by a melting glacier.

A. ZIMMER

When glaciers melt, they leave behind barren landscapes that can take decades to support plants and animals. In Peru, introducing llamas to freshly exposed land can quickly revitalize it, a new study finds, nourishing the soil and fostering plant growth.

By the foot of the shrinking Uruashraju Glacier in the Cordillera Blanca mountains, researchers partnered with local farmers to herd domesticated llamas on four designated plots. For three days a month from 2019 to 2022, the llamas grazed the plots, fertilizing them with dung and dispersing viable seeds from droppings and fur.

By the end of that time, the previously arid and easily eroded soil stabilized, grew richer in nutrients and supported 57 percent more plant cover than before, geographer Anaïs Zimmer and colleagues report September 24 in *Scientific Reports*.

Reviving the ancestral Andean practice of camelid herding, which declined under European colonization, could potentially cushion the crops, animals and livelihoods of local communities from the impacts of climate change, says Zimmer, of the University of Texas at Austin.

Glaciers are disappearing at an unprecedented rate worldwide, including in the Cordillera Blanca mountains. As the ice shrinks, nearby ecosystems wither: They lose access to summertime supplies of freshwater and can encounter harmful minerals once covered by the glaciers.

Llamas may help counter some of these effects. Their transformation of the land, as seen in the new study, could reduce rock weathering and thus limit the mineral runoff that poisons farmers' crops. (Such contamination is one reason the local farmers partnered with the researchers.) The animals' behavior could even generate pastureland as soil quality improves.

The idea that herbivore grazing may positively impact landscapes is not new. Nor is rewilding, which involves reintroducing key species to native ecosystems. In Finland, for example, the Indigenous Sámi are working to reinstall reindeer in deforested taiga land, potentially restoring it. And a group in Spain hopes one day to lift the wild bovine known as the aurochs out of extinction, putting it to use grazing.

But the size and speed of the changes the llamas helped bring about surprised Zimmer and colleagues. From 2021 to 2022, following two years of sparse growth, the average amount of plant cover in the llama plots grew from about 9 percent to nearly 14 percent. And four new plant species had moved in.

In four plots without llamas, average plant cover increased by just 31 percent, growing from about 10 percent to nearly 13 percent in the same time period. And no new plant species took root in those plots.

The research underscores the valuable roles animals play in shaping landscapes, says ecologist Kelsey Reider of James Madison University in Harrisonburg, Va., who was not involved in the research. Sprinkling nutrients such as phosphorus over the soil can produce similar effects on plant growth, she says, but "the animals themselves are doing a lot."

For one, dung retains both moisture and microbes. For another, llamas grazing and trampling on dominant plants makes space for new species.

Zimmer and colleagues chose to work with llamas rather than another native camelid, the vicuña, because llamas are easier to herd and are gentler tramplers. Farmer collaborators were also invested in restoring llama populations, features of Inca religious rituals. Centuries of Spanish colonization replaced llamas and other camelids with foreign livestock that uprooted native plants. Bringing llamas back, the farmers think, might slow or reverse the physical and cultural loss.

Zimmer would like to continue the study for at least a decade to track the full effects of the intervention. While the llamas might help a bevy of plants survive in the region, she says, which plants will stick around and whether they ultimately help or harm the ecosystem remains unclear.

The precise results matter less to Reider than the communities' needs. "If the locals want to increase plant cover because they understand, 'Hey, this will help us have a livelihood under climate change,' then by all means, go ahead," she says.

Zimmer notes that the icy mountaintops also hold religious significance for some communities in Peru. As the glaciers melt away, some people feel as though they are "losing their cultural identities," Zimmer says. Scientists project that the Cordillera Blanca will be glacier-free by 2100 if the average global temperature continues rising at its current pace.

If further research with llamas bears positive results, Zimmer hopes local governments might invest in llama herding as an adaptation strategy. It can't bring back the glaciers. But, she says, it may return a sense of agency. ■

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HEALTH & MEDICINE

Spinal stem cells lure breast cancer

The newfound cells secrete a tumor-attracting protein

BY MEGHAN ROSEN

When breast cancer spreads, it often targets the spine. Now scientists may have finally discovered why.

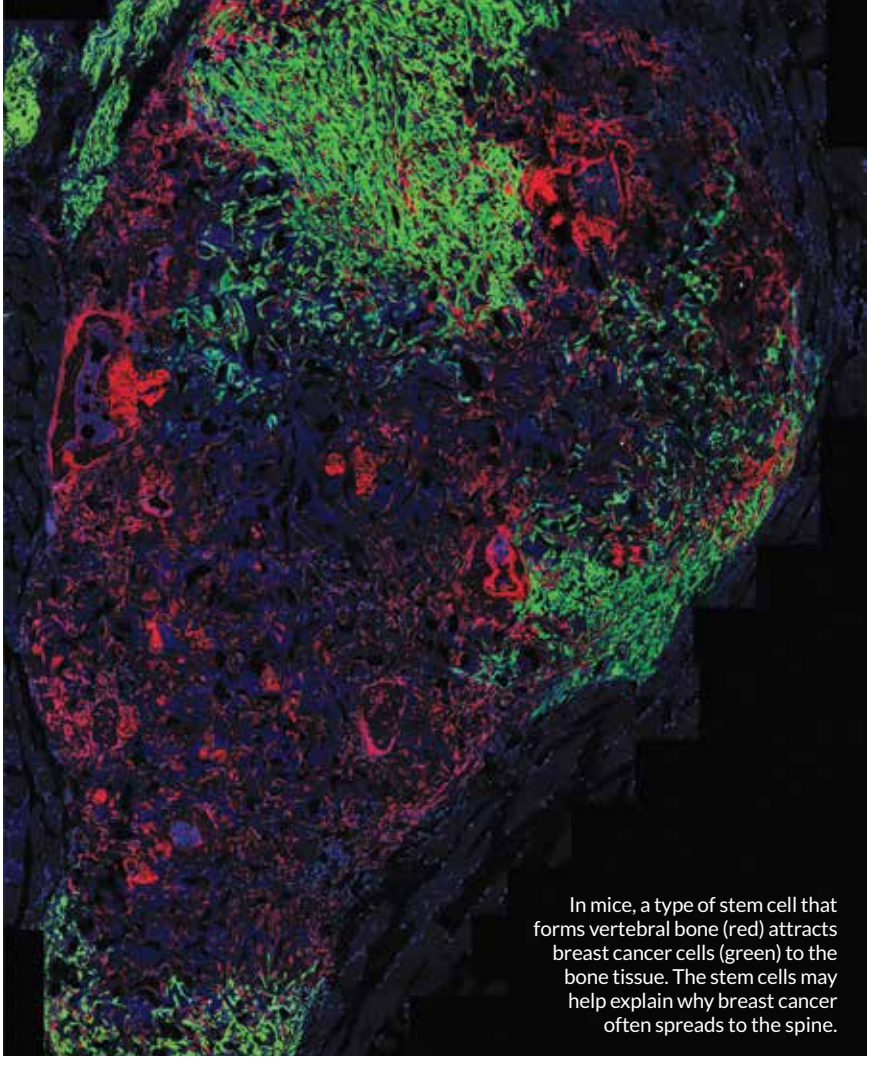
A newfound kind of stem cell drives cancer cells to bones in the vertebrae, pathologist Matthew Greenblatt of Weill Cornell Medicine in New York City and his colleagues report in the Sept. 21 *Nature*. The finding helps explain a long-standing mystery of metastasis: why some cancers break away from their site of origin, journey through the bloodstream and take up residence in the backbone.

"This is a major advance in our understanding of bone metastasis," says Xiang Zhang, a cancer biologist at Baylor College of Medicine in Houston who peer-reviewed the study.

In people with metastatic breast cancer, some 70 percent later develop bone cancer. And of the bones in the skeleton, cancer cells preferentially seek out vertebrae. For these patients, "spine metastases are one of the most common complications," Greenblatt says, "and one of the most dreaded." Tumors that take root in the spine can crush the spinal cord, which houses nerve bundles crucial for body sensation and movement. Such damage can hamper people's ability to walk and control their bladder and bowels, and can shorten their life spans.

Doctors have known for decades that some cancers preferentially seek out the spine, Greenblatt says, but no one has had a good explanation for why. One idea proposed in 1940, that actions like coughing jolt blood off course and somehow send cancerous cells to the vertebrae, still hangs on today. It's what Greenblatt learned when he was a medical student. But for him and his team, "that didn't make sense to us scientifically."

What did end up making sense was stem cells. The researchers had a hunch that stem cells inside vertebral bones differed from those in other sites in the skeleton, like the long bones in the arms and legs. In the lab, that's just what Greenblatt's team found. The researchers pulled out a population of stem cells from mice vertebrae distinctly unlike ones collected from long bones. These stem cells switched on a separate set of genes and behaved differently in experiments, the researchers found.



In mice, a type of stem cell that forms vertebral bone (red) attracts breast cancer cells (green) to the bone tissue. The stem cells may help explain why breast cancer often spreads to the spine.

J. SUN *ET AL*/*NATURE* 2023

Until now, scientists didn't know that these two types of bones held distinct populations of stem cells. "We assumed they were the same," says Geert Carmeliet, a cell and molecular endocrinologist at KU Leuven in Belgium who was not involved with the work. The discovery raises the possibility that spinal stem cells might play a role in spinal diseases.

In one key experiment, Greenblatt's team transplanted spinal stem cells into one hind leg of mice and long bone stem cells into the other. Each transplant formed miniature bone organoids in the animals' bodies—a tiny vertebra in the right leg, for example, and a bit of long bone in the left. Then, the researchers injected breast cancer cells into the mice and watched where they ended up.

The cells traveled to the mini vertebra nearly twice as often as they did to the little long bone, as if lured by a cancer-calling Pied Piper. It's an elegant way to show that "tumor cells preferentially come to the [vertebra] organoid and not to the organoid of the long bone," Carmeliet says.

The newly identified spinal stem cells, found in both mice and humans, secrete a protein called MFGE8 that draws cancer cells to spinal tissue, the team discovered. The protein may not be the only factor attracting tumors to the spine, Greenblatt says, "but it's an important one."

It's possible that blocking MFGE8 could prevent or treat spine metastasis. "I think it's definitely worth further investigation," Zhang says. But, he notes, it's still too early to know what the therapeutic implications may be. ■

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HEALTH & MEDICINE

Brain tissue may help fuel marathoners

Endurance athletes might tap into myelin for renewable energy

BY MEGHAN ROSEN

In endurance athletes, some brainpower may come from an unexpected source.

Marathon runners appear to rely on myelin, the fatty tissue bundled around nerve fibers, for energy during a race, scientists report October 10 in a paper posted at bioRxiv.org. In the day or two following a marathon, this tissue seems to dwindle drastically, brain scans of runners reveal. Two weeks after the race, the brain fat bounces back to nearly pre-race levels. The finding suggests that the athletes burn so much energy running that they need to tap into a new fuel supply to keep the brain operating smoothly.

"This is definitely an intriguing observation," says neuroimaging scientist Mustapha Bouhrara of the National Institute on Aging in Baltimore. "It is quite plausible that myelin lipids are used as fuel in extended exercise."

If what the study authors are seeing is real, the work could have therapeutic implications, he says. Understanding how runners' myelin recovers so rapidly might offer clues for developing potential treatments for people who have lost myelin due to aging or neurodegenerative disease.

Much of the human brain contains myelin, which insulates nerve fibers, like rubber coating an electrical wire. That insulation lets electrical messages zip from nerve cell to nerve cell, allowing high-speed communication that's crucial for brain function.

The fatty tissue seems to be a straightforward material with a straightforward job, but there's likely more to it than that, says Klaus-Armin Nave, a neurobiologist at the Max Planck Institute for Multidisciplinary Sciences in Göttingen, Germany. "For the longest time, it was thought that myelin sheaths were assembled, inert structures of insulation that don't change much after they're made."

Today, there's evidence that this myelin is a dynamic structure, growing and shrinking in size and abundance depending on cellular conditions. Myelin plasticity "is hotly researched," Nave says.

Fatty molecules and other myelin sheath components regularly turn over, breaking down the insulating material and building it back up again. In mice, brain cells can tap into these in-flux fats when sugar — the brain's typical energy source — is scarce, experiments by Nave's team have suggested.

Neurobiologist Carlos Matute of the Achucarro Basque Center for Neuroscience and the University of the Basque Country in Leioa, Spain, wondered if these fats could also sustain the brains of endurance athletes. He's a marathon runner and had been curious about how people's brains continued working after strenuous exercise drained the body's energy reserves.

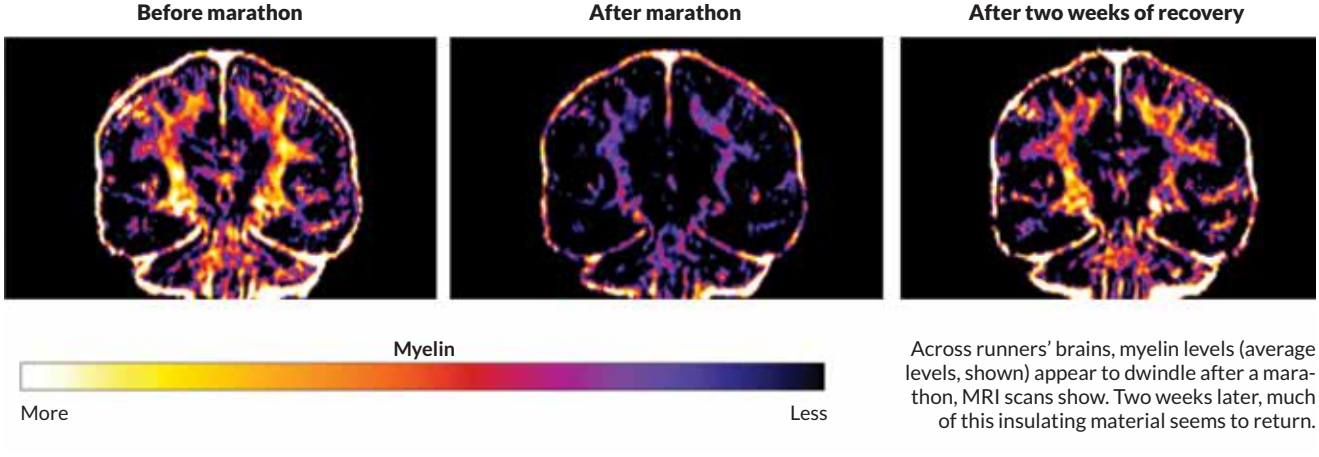
Using an MRI, Matute and colleagues scanned the brains of four marathon runners in the days before and after a race, and two of the runners two weeks later. A day or two after the race, the team saw a reduction in the amount of myelin in the brain. That suggested the myelin sheaths had thinned, Matute says. After two weeks, much of the myelin had returned, thickening around neural fibers.

That's a rapid decline followed by a rapid recovery, Bouhrara says, a drastic result that gives him pause. Matute and colleagues used water trapped between layers of myelin as a proxy for myelin content. More of this water indicates more myelin. But you can't rule out the effects of dehydration, Bouhrara says. If runners are dehydrated after their race, their brain tissues may just be dried out.

It's a point Matute has heard before, when presenting his data to colleagues. "In our opinion, this is not the case." His team scanned the runners days after their race, so they had time to rehydrate. What's more, the runners' brain volumes stayed nearly the same before and after the marathon. Dehydrated brains would probably be smaller, Matute says. "We saw that there is no shrinkage of the brain at all."

Next, Matute's team wants to see if the myelin dip alters brain function, and how long it takes to recover completely.

Matute points out that the new results don't mean running is bad for the brain. "Not at all," he says. It's possible that using and replenishing energy reserves is beneficial, because it exercises the brain's metabolic machinery. ■



Across runners' brains, myelin levels (average levels, shown) appear to dwindle after a marathon, MRI scans show. Two weeks later, much of this insulating material seems to return.

P. RAMOS-CABRER *ET AL*/BIORXIV.ORG 2023

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It was a warm summer afternoon and my wife and I were mingling with the best of them. The occasion was a 1920s-themed party, and everyone was dressed to the nines. Parked on the manse's circular driveway was a beautiful classic convertible. It was here that I got the idea for our new 1920s Retrograde Watch.

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THE CLIMATE FIX

This article is part of a series of stories on climate change solutions and how people around the world are tackling the biggest challenge of our time.

Clear the Air

Scientists are racing to develop methods to remove methane from the atmosphere and slow global warming

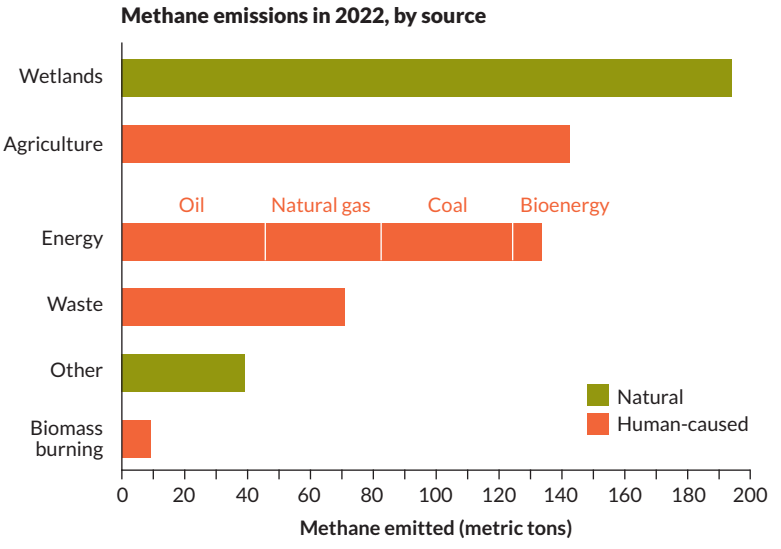
By Katherine Bourzac

Fossil fuel activities, including the flaring of natural gas at oil refineries (shown), release climate-warming methane into the atmosphere.

FROM LEFT: HHAKIM/E+/GETTY IMAGES PLUS; C. CHANG

This summer was the hottest ever recorded on Earth, and 2023 is on track to be the hottest year. Heat waves threatened people's health across North America, Europe and Asia. Canada had its worst wildfire season ever, and flames devastated the city of Lahaina in Maui. Los Angeles was pounded by an unheard-of summer tropical storm while rains in Libya caused devastating floods that left thousands dead and missing. This extreme weather is a warning sign that we are living in a climate crisis, and a call to action.

Carbon dioxide emissions from burning fossil fuels are the main culprit behind climate change, and scientists say they must be reined in.



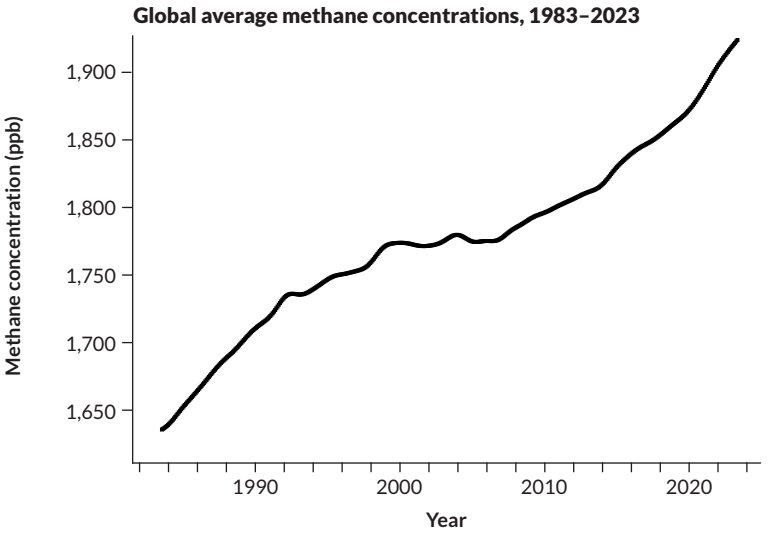
Methane culprits
Experts estimate that in 2022, about 590 million metric tons of methane were released into the atmosphere. About 60 percent of those emissions came from human activities.
SOURCE: GLOBAL METHANE TRACKER/IEA 2023

But there's another greenhouse gas to deal with: methane. Tackling methane may be the best bet for putting the brakes on rising temperatures in the short term, says Rob Jackson, an Earth systems scientist at Stanford University and chair of the Global Carbon Project, which tracks greenhouse gas emissions. "Methane is the strongest lever we have to slow global warming over the next few decades."

That's because it's relatively short-lived in the atmosphere — methane lasts about 12 years, while CO_2 can stick around for hundreds of years. And on a molecule-per-molecule basis, methane is more potent. Over the 20-year period after it's emitted, methane can warm the atmosphere more than 80 times as much as an equivalent amount of CO_2.

We already have strategies for cutting methane emissions — fixing natural gas leaks (methane is the main component of natural gas), phasing out coal (mining operations release methane), eating less meat and dairy (cows burp up lots of methane) and electrifying transportation and appliances. Implementing all existing methane-mitigation strategies could slow global warming by 30 percent over the next decade, research has shown.

But some climate scientists, including Jackson, say we need to go further. Several methane sources will be difficult, if not impossible, to eliminate. That includes some human-caused emissions, such as those produced by rice paddies and cattle farming — though practices do exist to reduce these emissions (SN: 11/28/15, p. 22). Some natural sources are poised to release more methane as the world warms. There are signs that tropical wetlands are already releasing more of the gas into the atmosphere, and rapid warming in the Arctic could turn permafrost into a hot spot for methane-making



On the rise Over the last 40 years, the concentration of methane in the atmosphere has steadily risen, with a lull in the late 1990s and 2000s. Overall, the amount of methane in the atmosphere has more than doubled over the last 200 years.

microbes and release a bomb of methane stored in the currently frozen soil.

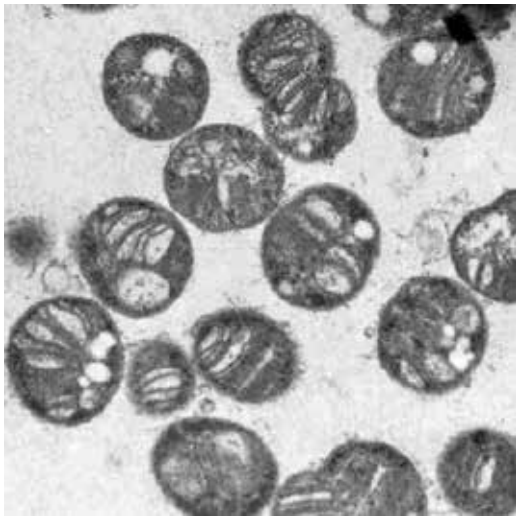
So scientists want to develop ways to remove methane directly from the air.

Three billion metric tons more methane exist in the atmosphere today than in preindustrial times. Removing that excess methane would cool the planet by 0.5 degrees Celsius, Jackson says.

Similar "negative emissions" strategies are already in limited use for CO_2. That gas is captured where it's emitted, or directly from the air, and then stored somewhere. Methane, however, is a tricky molecule to capture, meaning scientists need different approaches.

Most ideas are still in early research stages. The National Academies of Sciences, Engineering and Medicine is currently studying these potential technologies, their state of readiness and possible risks, and what further research and funding are needed. Some of the approaches include re-engineering bacteria that are already pros at eating methane and developing catalytic reactors to place in coal-mine vents and other methane-rich places to chemically transform the gas.

"Methane is a sprint and CO_2 is a marathon," says Desirée Plata, a civil and environmental engineer at MIT. For scientists focused on removing greenhouse gases, it's off to the races.



Some bacteria, including *Methylococcus capsulatus* (shown), naturally break down methane with the enzyme methane monooxygenase. By studying the enzyme's structure, scientists hope to speed up bacteria's uptake of the greenhouse gas.

Microbial masters

Methane, CH_4, is readily broken down in the atmosphere, where sunshine and highly reactive hydroxyl radicals are abundant. But it's a different story when chemists try to work with the molecule. Methane's four carbon-hydrogen bonds are strong and stable. Currently, chemists must expose the gas to extremely high temperatures and pressures to break it down.

Even getting hold of the gas is difficult. Despite its potent warming power, it's present in low concentrations in the atmosphere. Only 2 out of every 1 million air molecules are methane (by comparison, about 400 of every 1 million air molecules are CO_2). So it's challenging to grab enough methane to store it or efficiently convert it into something else.

Nature's chemists, however, can take up and transform methane even in these challenging conditions. These microbes, called methanotrophs, use enzymes to eat methane. The natural global uptake of methane by methanotrophs living in soil is about 30 million metric tons per year. Compare that with the roughly 350 million tons of methane that human activities pumped into the atmosphere in 2022, according to the International Energy Agency.

Microbiologists want to know whether it's possible to get these bacteria to take up more methane more quickly.

Lisa Stein, a microbiologist at the University of Alberta in Edmonton, Canada, studies the genetics and physiology of these microbes. "We do basic research to understand how they thrive in different environments," she says.

Methanotrophs work especially slowly in low-oxygen environments, Stein says, like wetland muck and landfills, the kinds of places where methane is plentiful. In these environments, microbes that make methane, called methanogens, generate the gas faster than methanotrophs can gobble it up.

But it might be possible to develop soil amendments and other ecosystem modifications to speed microbial methane uptake, Stein says. She's also talking with materials scientists about engineering a surface to encourage methanotrophs to

grow faster and thus speed up their methane consumption.

Scientists hope to get around this speed bump with a more detailed understanding of the enzyme that helps many methanotrophs feast on methane. Methane monooxygenase, or MMO, grabs the molecule and, with the help of copper embedded in the enzyme, uses oxygen to break methane's carbon-hydrogen bonds. The enzyme ultimately produces methanol that the microbes then metabolize.

Boosting MMO's speed could not only help with methane removal but also allow engineers to put methanotrophs to work in industrial systems. Turning methane into methanol would be the first step, followed by several faster reactions, to make an end product like plastic or fuel.

"Methane monooxygenases are not superfast enzymes," says Amy Rosenzweig, a chemist at Northwestern University in Evanston, Ill. Any reaction involving MMO will impose a speed limit on the proceedings. "That is the key step, and unless you understand it, it's going to be very difficult to make an engineered organism do what you want," Rosenzweig says.

Enzymes are often shaped to fit their reactants—in this case, methane—like a glove. So having a clear view of MMO's physical structure could help researchers tweak the enzyme's actions. MMO is embedded in a lipid membrane in the cell. To image it, structural biologists have typically started by using detergents to remove the lipids, which inactivates the enzyme and results in an incomplete picture of it and its activity. But Rosenzweig and colleagues recently managed to image the enzyme in this lipid context. This unprecedented view of MMO in its native state, published in 2022 in *Science*, revealed a previously unseen site where copper binds.

But that's still not the entire picture. Rosenzweig says she hopes her structural studies, along with other work, will lead to a breakthrough soon enough to help forestall further consequences of global warming. "Maybe people get lucky and engineer a strain quickly," Rosenzweig says. "You don't know until you try."

Climate catalysts

Other scientists seek to put methane-destroying chemical reactors close to methane sources. These reactors typically use a catalyst to speed up the chemical reactions that convert methane into a less planet-warming molecule. These catalysts often require high temperatures or other stringent conditions to operate, contain expensive metals like platinum, and don't work well at the concentrations of methane found in ambient air.

One promising place to start, though, is coal mines. Coal mining is associated with tens of millions of tons of methane emissions worldwide every year. Although coal-fired power plants are being phased out in many countries, coal will be difficult to eliminate entirely due to its key role in steel production, says Plata, of MIT.

To develop a catalyst that might work in a coal mine, Plata found inspiration in MMO. Her team developed a catalyst material based on a silicate material embedded with copper—the same metal found in MMO and much less expensive than those usually required to oxidize methane. The material is also porous, which improves the catalyst's efficiency because it has a larger surface area, and thus more places for reactions to occur, than a nonporous material would. The catalyst turns methane into CO_2, a reaction that releases heat, which is needed to further fuel the reaction. If methane concentrations are high enough, the

At Drumgoon Dairy in South Dakota, Elijah Martin (left) and Will Sawyer (right) test a small-scale thermal catalytic unit developed in Desirée Plata's lab at MIT. The reactor transforms methane into carbon dioxide, which could lower the planet's net warming rate because methane is a stronger greenhouse gas.

D. PLATA

reaction will be self-sustaining, Plata says.

Turning methane into CO_2 may sound counterproductive, but it reduces warming overall because methane traps much more heat than CO_2 and is far less abundant in the atmosphere. If all the excess methane in the atmosphere were turned into CO_2, according to a 2019 study led by Jackson, it would result in only 8.2 billion additional tons of CO_2 — equivalent to just a few months of CO_2 emissions at today's rates. And the net effect would be to lessen the heating of the atmosphere by a sixth.

Cattle feedlots are another place where Plata's catalytic reactor might work. Barns outfitted with fans to keep cattle comfortable move air around, so reactors could be fitted to these ventilation systems. The next step is determining whether methane concentrations at industrial dairy farms are high enough for the catalyst to work.

Another researcher making progress is energy scientist and engineer Arun Majumdar, one of Jackson's collaborators at Stanford. In January, Majumdar published initial results describing a catalyst that converts methane into methanol, with an added boost from high-energy ultraviolet light. This UV blast adds the energy needed to overcome CH_4's stubborn bonds — and the carefully designed catalyst stays on target. Previous catalyst designs tended to produce a mix of CO_2 and methanol, but this catalyst mostly sticks to making methanol.

"Methane is a sprint and CO_2 is a marathon."
DESIRÉE PLATA

Engineering the atmosphere

A more extreme approach to speed up methane's natural breakdown is to change the chemistry of the atmosphere itself. A few companies, such as the U.S.-based Blue Dot Change, have proposed releasing chemicals into the sky to enhance methane oxidation.

Natalie Mahowald, an atmospheric chemist at Cornell University, decided to evaluate this type of geoengineering.

"I'm not super excited about throwing more things into the atmosphere," Mahowald says. To meet the goals of the Paris Agreement, limiting global warming to 1.5 to 2 degrees Celsius above the preindustrial average, though, it's worth exploring all possibilities, she says. "If we're going to meet these targets," she says "we're going to need some of these crazy ideas to work. So I'm willing to look at it. But I'm looking with a scientist's critical eye."

The main strategy proposed by advocates would inject iron aerosols into the air over the ocean on a sunny day. These aerosols would react with salty sea spray aerosols to form chlorine, which would then attack methane in the atmosphere and initiate further chemical reactions that turn it into CO_2. Mahowald wondered how much chlorine would be needed — and if there might be any unintended consequences.

Detailed modeling revealed something alarming. The iron injections could have the opposite of the intended effect, Mahowald and colleagues reported in July in *Nature Communications*. Chlorine won't attack methane if ozone is around. Instead, chlorine will first break down all the ozone it can find. But ozone plays a key role in generating the hydroxyl radicals that naturally break down atmospheric methane. So when ozone levels fall, Mahowald says, the concentration and lifetime of methane molecules in the atmosphere actually increases. To use this strategy to break down methane, geoengineers would need to add a tremendous amount of chlorine to the atmosphere — enough to first break down the ozone, then attack methane.

Removing 20 percent of the atmosphere's methane, thus reducing the planet's surface temperature by 0.2 degrees Celsius by 2050, for example, would require creating about 630 million tons of atmospheric chlorine every year. That would in turn require injecting perhaps tens of millions of tons of iron. A form of particulate matter, these iron aerosols could worsen air quality; inhaling particulate matter is associated with a range of health problems, particularly cardiovascular and lung disease. This atmospheric tinkering could also create hydrochloric acid that could reach the ocean and acidify it.

And there's no guarantee that some of the chlorine wouldn't make it all the way up to the ozone layer, depleting the planetary shield that protects us from the sun's harmful UV rays. Mahowald is still studying this possibility.

Mahowald is ambivalent about doing research on geoengineering. "We're just throwing out ideas here because we're in a terrible, terrible position," she says. She's worried about what could happen if all the methane locked up in the world's permafrost escapes. If scientists can figure out how to use iron aerosols effectively, without adverse effects — and if such geoengineering is accepted by society — we might need it.

"We're just trying to see, is there any hope this could work and would we ever want to do it? Would it have enough benefits to outweigh the disadvantages?"

The committee organized by the National Academies to investigate methane removal is taking these kinds of ethical questions into account, as well as considering the potential cost and scale of technologies.

Nipping methane in the gut

On a hot July afternoon in Northern California, dairy cattle cluster in the shade of an open-sided barn. Fans mounted to the ceiling keep the air moving and provide a bit of relief from the sweltering heat.

These cows, part of a research herd at the University of California, Davis, may be the future subjects in a study on how to curb methane emissions from cattle.

Livestock are responsible for over 30 percent of human-caused methane emissions each year. Manure is a big source of that methane, and cow burps are an even bigger one. In the past, researchers have tried altering cattle feed, selective breeding and even vaccines to lower the livestock's methane emissions.

But at UC Davis, scientists are attempting to re-engineer the microbes inside cow rumens that produce the gas. The aim is to alter the microbial genes responsible for generating methane, using the molecular scissors known as CRISPR. The first step is to find those genes.

Microbiologist Matthias Hess has taken up that challenge. The counters in his UC Davis lab are lined with bottles of bright yellow liquid. A funky, barnyard smell in the air attests to the fact these bottles contain cow rumen samples. Isolating individual microbes from this complex microbial soup is a challenge, Hess says. So his team is sequencing all the DNA present in a microbiome sample to find the genes for methane production.

Once the target genes are discovered, the next step will be to see if they can be edited. Hess and UC Davis animal scientist Ermias Kebreab are collaborating with Jennifer Doudna, the biochemist at the University of California, Berkeley who shared the 2020 Nobel Prize in chemistry for the development of CRISPR, and UC Berkeley microbiologist Jill Banfield. The group had its first meeting in late July, and if things go well, Hess says, a CRISPR technique may be ready for testing in cattle in three or four years.

This cow is part of a research herd at the University of California, Davis.

If gene editing works, the team plans to develop a treatment to give young calves that would deliver altered genes to microbes in the rumen, reconfiguring the microbiome so that the cows can still digest food but without burping methane. Since cows pass on their microbes to their calves, these alterations might be passed on too.

—Katherine Bourzac

Stein, a committee member, says a framework proposed by Spark Climate Solutions provides some guidance. The organization, a nonprofit based in San Francisco that evaluates methane-removal technologies, proposes investing in tech that can remove tens of millions of tons of methane per year in the coming decades, at a cost of less than $2,000 per ton. Spark cofounder David Mann says the numbers are designed to focus attention and investment on technologies that can make a real difference in curbing climate change in the near term.

The National Academies group aims to make recommendations about research priorities on methane-removal technologies by next summer. It's likely that a portfolio of different technologies will be necessary. What works in a cattle feedlot may not work at a wastewater treatment plant, for instance.

Scientists focused on methane removal are eager for more researchers, research funding and companies to enter the fray—and quickly. "It's been a crazy year," Jackson says of 2023's extreme weather. We're already feeling the effects of global warming, but we can seize the moment, he says. "This problem is not something for our grandchildren. It's here." ■

Explore more

- Read about the National Academies of Sciences, Engineering and Medicine's methane-removal research agenda at bit.ly/MethaneRemoval

Katherine Bourzac is a freelance science journalist based in San Francisco.

K. BOURZAC

Healing practitioners Kristin Stevenson, Lynn Williams and Todd Womack, from left, lead healing circles in Flint to bring people together to share their stories and build relationships.

JENIFER VELOSO

Caring for **community**

Residents of Flint, Mich., are still healing from the devastating water crisis that began almost a decade ago

By Aimee Cunningham

On a Saturday in May in Flint, Mich., residents took seats in one of three rings of chairs at a local food bank. The 50 or so participants, spanning three generations, would spend time that morning sharing stories and practicing deep listening as part of a healing circle. It's one component of a wider community-based movement to build relationships and challenge racist beliefs and systems.

In one circle, healing practitioner Todd Womack asked participants to introduce themselves and describe their favorite desserts. Fingers snapped softly to signal mutual enjoyment. Next, participants paired off, with instructions to take turns asking about something that recently made them smile or laugh — and to listen without interruption. From there, new pairs moved to other topics, such as an accomplishment they were proud of.

Healing circles are a space to foster community, says Lynn Williams, the director of equity and community engagement at the Community Foundation of Greater Flint, who helped organize the event that morning. The circles allow room for "healing of trauma from systems, from oppression, from negativity," she

says. And they provide a place to tell a community's full story, to "highlight the assets and the cultural contributions."

The circles are one way to let people know they matter when society keeps telling them they don't.

The residents of Flint — a city with a majority Black population and many people experiencing poverty — know this disregard well. In April 2014, to cut costs, state officials switched the city's water source from Lake Huron to the Flint River without an adequate treatment plan. The public health catastrophe that has followed "is a story of government failure, intransigence, unpreparedness, delay, inaction and environmental injustice," according to the final report from the Flint Water Advisory Task Force, commissioned to find the causes of the water disaster. The human-made crisis turned a necessity into a hazard for the residents of the city, which had a population of around 99,000 at the time. The lack of proper treatment exposed people to bacteria, excessive disinfection chemicals and lead.

Residents reported that their physical health suffered. People broke out in rashes, lost hair and had gastrointestinal illnesses. Researchers found an association between a local, deadly Legionnaires' disease outbreak in 2014–15 and insufficient disinfection in the water system. Many children have developed health and behavioral problems from lead poisoning. "I am so upset," says Bishop Bernadel Jefferson of Faith Deliverance Center in Flint, speaking of her grandson's lead exposure and subsequent learning difficulties. "The system failed him."

Mental health has suffered, too. Residents have reported experiencing depression, anxiety and post-traumatic stress disorder. With disasters, especially those that involve toxic exposures, "the emotional consequences are long-term, because they're fueled by this concern [that] health or cognitive functioning has been forever adversely affected," says Evelyn Bromet, a psychiatric epidemiologist at the Renaissance School of Medicine at Stony Brook University in New York who has studied the Chernobyl nuclear power plant disaster.

For a year and a half, officials dismissed residents' concerns about the safety of the water. "It was horrifying, because not only were they not believed, but they weren't taken seriously," Bromet says. The anger that goes along with that "is of course a detrimental emotional state to be in for a long period of time."

Other difficult experiences compounded the anguish that came with the water disaster. "This community has been exposed to multiple traumas," says Womack, a social worker at the University of Michigan–Flint. When the disaster began, Flint was still struggling with the loss of tens of thousands of jobs due to General Motors' layoffs and plant closures from the 1970s to the 1990s. The COVID-19 pandemic began as the water disaster continued.

Mental health remains a pressing concern for the community. But there aren't enough mental health providers to meet the need, says Barbara Wolf, a clinical health psychologist at McLaren Health Care in Flint. Genesee County, which includes Flint, is among the areas in the United States with a shortage of mental health professionals, according to the U.S. Department of Health and Human Services.

Flint residents have a long history of activism, including the sit-down strike of 1936–37 by General Motors workers, who remained in the plants to stop production (Fisher body plant factory No. 3 is shown).

Community activism was instrumental in bringing attention to the Flint water crisis. Here, Gladyes Williamson and others protest in April 2015 in downtown Flint.

So, as they've done before, Flint residents are finding a way. It was the community's organizing and activism that brought attention to the water disaster. And as Flint approaches 10 years since the disaster began, local organizations continue to help the community heal. There are mental health and resiliency trainings, mindfulness meditation and community conversations about mental health. "There's not just one approach," says Kristin Stevenson, project manager for the Flint Resiliency in Communities After Stress and Trauma, or ReCAST, program at the Greater Flint Health Coalition, and a healing practitioner. "All of these things combined are what create the impact."

What has happened in Flint — and what continues there — illustrates a community's activism and perseverance, as well as the mental health fallout of a disaster. But this story won't end in Flint. Communities across the country could find themselves part of the next chapter, their lives upended by catastrophe. The United States' aging water infrastructure has led to other water crises and could trigger more. Wildfires, hurricanes and floods, fueled by climate change and other human-caused environmental changes, are increasing in frequency and destructiveness. Mental health will suffer in the aftermath of these traumatic events. The

FROM TOP: SHELDON DICK/LIBRARY OF CONGRESS; SAM OWENS/*THE FLINT JOURNAL*-MLIVE.COM/ASSOCIATED PRESS

water disaster in Flint can be seen as both a warning and a model of community response.

"We recognize that our struggle, if not now, will become yours," Womack says.

The making of a disaster

A decorative archway spanning one of downtown Flint's main thoroughfares reads "Flint: Vehicle City." The city was home to a booming carriage business before General Motors was founded there in 1908. Residents look back with pride on the community's activism during GM workers' famous sit-down strike for better pay and recognition of their union, the United Auto Workers. For around six weeks in 1936–37, striking workers occupied factories to stop production. Family and community members provided supplies and support from the outside. The strike heralded the rise of the labor movement in the automotive industry.

As in other cities, Flint's industrial growth was detrimental to its river, as factories would discharge waste directly into the water. The Clean Water Act of 1972, which regulates pollution from industrial and municipal sources, has improved the health of U.S. waterways, including Flint's. In 1974, the Safe Drinking Water Act was enacted to safeguard the country's drinking water. The law sets standards for levels of contaminants, including microorganisms, chemicals and metals such as lead.

In 2014, Flint's water treatment plant hadn't been fully operational for almost 50 years. Instead, the city had been purchasing treated Lake Huron water from Detroit's water utility. But an unelected emergency manager, placed in charge of Flint's finances by Michigan's then-Governor Rick Snyder, had authorized a switch to the Flint River as a cost-saving measure. Water treatment is a complex process, and the Flint River water was more corrosive than other water sources. But the Flint plant didn't test its treatment procedures sufficiently, according to an analysis by water treatment experts. In violation of federal requirements, there was no corrosion control treatment, which helps prevent lead from leaching into the water as it moves through the distribution system's pipes.

When residents turned on their faucets in the weeks after the switch on April 25, they were unsettled by what came out. "I used to love tap water, just to run it and let it get cold," Jefferson says. But after the switch, the water left a film in her mouth. Flint resident Gina Luster liked to chew ice, but it started to taste "like metal, like I'm chewing steel." Cynthia Watkins, apostle at the Well International Church Ministries in Flint, remembers the water "just smelling, it was horrible." For Roshanda Womack, a professional storyteller and spouse of Todd Womack, the water had a strong odor and was sometimes cloudy or had a slight brown tinge to it.

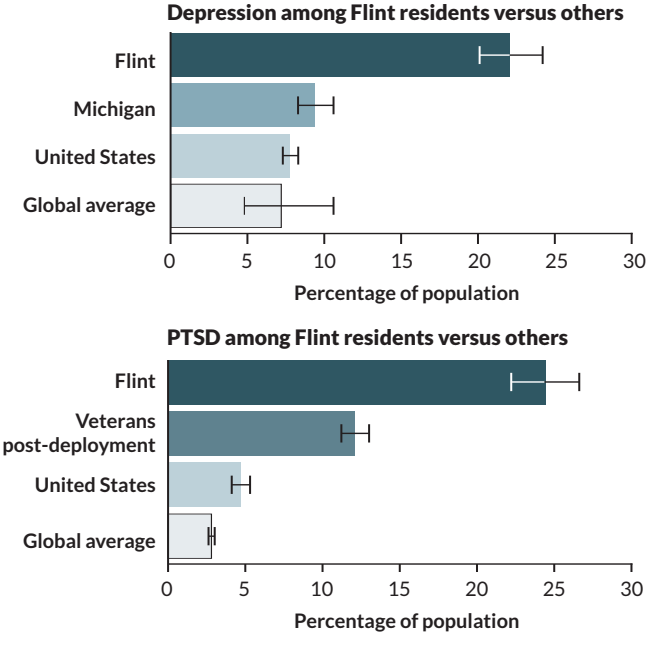
People in the community spoke out about the poor water quality, with some reporting rashes from exposure to the water. But officials maintained that the water was safe for use.

Warning signs mounted in the following months. The water in the distribution system tested positive in August for *E. coli*, which can indicate fecal contamination and inadequate disinfection. This prompted a boil water advisory. In October, General Motors announced that it would stop using the city's water at an engine plant over concerns about corrosion. While the company switched to a different water supply for manufacturing, officials still claimed Flint's water met safety standards for people. Throughout 2014, church leaders and other community members worked to elevate people's concerns about the water.

At the end of 2014, the city was served with a Safe Drinking Water Act violation, having exceeded allowable levels of trihalomethanes, disinfection by-products tied to an increased risk of cancer. These chemicals form when disinfectant added during treatment reacts with naturally occurring materials in river and lake water. One of the challenges of water treatment is maintaining proper disinfection while limiting by-product chemicals.

After the public notice of the violation in January 2015, Flint resident LeeAnne Walters asked the city to test her water. Samples from February and March revealed lead levels around seven and 27 times what spurs regulatory action. Walters' home plumbing was plastic. An analysis of the city service line to the house revealed it was the source of the lead. When Walters' 4-year-old son was tested for lead in March, his level was 6.5 micrograms per deciliter. No amount of lead is considered safe. At the time, the U.S. Centers for Disease Control and Prevention used a reference value of 5 µg/dL, developed based on national surveys, to identify kids with the highest lead levels. In 2021, the CDC lowered that reference value to 3.5 µg/dL.

As the year continued, local organizations and churches formed the Coalition for Clean Water, which passed out flyers to inform



Lingering effects More than 20 percent of nearly 2,000 adult Flint residents surveyed about five years after the water crisis began met the criteria for past-year depression. Nearly 25 percent met the criteria for past-year post-traumatic stress disorder, above the percentage for post-deployment Gulf War veterans. SOURCE: A. REUBEN *ET AL/JAMA NETWORK OPEN* 2022

T. TIBBITTS

Youth Arts: Unlocked provides art workshops to young people at the Genesee County Juvenile Justice Center. Visual arts teacher Sharlene L. Howe (center), who works with the organization, discusses some of the young artists' work at an art walk event in October. Youth Arts: Unlocked is one of several local organizations funded by ReCAST, which seeks to address trauma and stress in the community.

JENIFER VELOSO

residents of the water safety issues and collected water samples for testing. People protested, with rallies in Flint, Detroit and Lansing, the state capital. In August, organizers delivered to the mayor a petition, with more than 26,000 signatures, demanding to switch back to water from the Detroit system.

Then, at a September news conference, local researchers announced an alarming rise in the percentage of Flint children with lead levels of 5 μg/dL or higher. The analysis included children younger than age 5 who had had their levels checked as part of routine lead screening—736 children in 2013, before the water source changed, and 737 after, in 2015. The percentage of kids considered to have high lead levels increased from 2.4 percent in 2013 to 4.9 percent in 2015, the researchers reported in 2016 in the *American Journal of Public Health*. In neighborhoods with the most lead in the water, the jump was from 4.0 to 10.6 percent. A similar change was not seen in 2,202 children who lived outside of the city and had a different water source.

Lead harms children's developing brains and nervous systems. Studies have found that the metal disrupts communication between nerve cells and impairs the hippocampus, a brain region important in learning and memory. Children exposed to lead can develop learning disabilities, speech and hearing disorders, and behavioral problems. The damage can shape the rest of their lives.

Officials ultimately couldn't brush aside the evidence of poisoned children. The city reconnected to the Detroit water system on October 16, 2015. But that water still had to flow through Flint's pipes, which had become corroded. The city has been replacing its lead service lines but has repeatedly missed court-ordered deadlines and still isn't finished. Lead levels have been in compliance with federal regulations since 2016 but have fluctuated recently. In 2022, lead levels rose to the highest seen in six years.

"We're still not fixed," says Kent Key, a health disparities researcher at the Flint campus of Michigan State University's College of Human Medicine.

The Flint Water Advisory Task Force reported that the state government was primarily responsible for the water disaster.

Living in anguish

The Flint community organized, rallied and distributed testing kits and bottled water while people there lived through a disaster. "The water disaster was a traumatic experience," Todd Womack says. "At the time, I don't think people were saying it was traumatic. I think they were saying, 'How do we get this basic need?'"

Eventually, the trauma rose to the surface. There had been so much worry, stress, anger and grief. Parents who had cajoled their kids to choose water over soda and juice were distraught. "I feel so guilty now," Luster says. "I was poisoning my kid." Pets died unexpectedly, which seemed to be tied to drinking the water. "I ended up losing both my dogs," Watkins says. "That was just devastating." Getting enough bottled water was a financial hardship for many. "I watched people, low-income families or on a fixed income … take half of their money to buy water every month," Jefferson says.

And for so long, residents were told, "'You're paranoid, you're crazy, the water is fine,'" Roshanda Womack says, "when you can see it's not fine." Jennifer Carrera, an environmental sociologist at Michigan State University in East Lansing, says there were "so many ways in which the treatment of the residents minimized their experiences…. Gaslighting is a very fair way of characterizing what happened to Flint residents."

Yet General Motors got a different water supply for its plant. "For parts, for automobile parts," Jefferson says, but not for people. "It was all right for us to be poisoned. It was all right to be sick. It was all right to die."

Dionna Brown, a sociology graduate student at Wayne State University in Detroit, grew up in Flint and was a teenager during the water disaster. Brown felt "like the government is trying to poison a Black city." She realized, "Black children, we can't have a childhood. We have to grow up fast."

"To live with that level of betrayal," says Bromet, the Stony Brook psychiatric epidemiologist, "of course it takes its toll."

As does the lack of justice. "The perpetrator, in a just and fair society, is held accountable," Key says. "In the Flint water crisis, that still hasn't happened." The city has been "forced to work with the perpetrator, the state, to work towards recovery."

The experience has left many unconvinced that the city's water is safe. "I think you're just going to have a large portion of the population that is never going to drink the water again," says social epidemiologist Jerel Ezell of the University of California, Berkeley, who grew up in the Flint suburbs.

Worrying about water "puts a strain on you," says Flint resident Tyshae Brady. "I don't want to always go over to a friend's house and go, 'Hey, is your water safe to drink?'" The unease extends beyond Flint, too. Flint church elder Sarah Bailey, who has worked on stroke prevention in the community and other projects, recalls being at a Boston restaurant with colleagues. "The waitress brings some water to the table in glasses, and I reach over and say, 'Do you happen to have any bottled water?'" One of her colleagues told Bailey the water was safe. "I said, 'For you.... The water was not safe for me.'"

The mental health aftermath

The disaster has weighed heavily on the mental health of residents, both children and adults. From December 2018 to March 2020, researchers surveyed the caregivers of 1,203 children, ages 3 to 17. The caregiver-reported rates of anxiety and depression among the children were 13 percent for anxiety and 8 percent for depression, higher than the national rates of 9 and 4 percent for that age group, the researchers reported in September in the *American Journal of Public Health*.

A different research team surveyed 1,970 adult residents from August 2019 to April 2020—around that time, Flint's total population was just over 81,000. Twenty-two percent of the respondents had experienced symptoms of depression in the past year, while 24 percent met criteria for post-traumatic stress disorder. That's higher than the estimated past-year rates, 8 percent for depression and 5 percent for PTSD, for the U.S. population. Extending the findings to Flint's population suggests that around 13,600 adults may have experienced depression and around 15,000 may have had PTSD, the researchers reported in 2022 in *JAMA Network Open*.

People who were worried the water had harmed their or their family's health were more than twice as likely to meet the criteria for depression and about 1.7 times as likely for PTSD, compared with people without this concern.

Past tragedies, such as a serious accident, physical abuse, sexual assault or a previous environmental calamity, can increase mental health risks when disaster strikes. "Your cumulative exposure to potentially traumatic events drives a lot of the risk for either developing or maintaining PTSD or depression," says Dean Kilpatrick, a clinical psychologist at the Medical University of South Carolina in Charleston and one of the authors of the study in adults. Kilpatrick and colleagues found that the risk of developing symptoms of depression increased by a factor of close to three, and for PTSD symptoms by a factor of 4.6, for Flint residents with past exposure to a potentially traumatic event, compared with those without.

35
percent
Survey respondents who reported being offered mental health care related to the water disaster

For some, mental health issues from disasters may persist for years. Researchers followed mothers who experienced Hurricane Katrina and had incomes less than twice the federal poverty line. The women were surveyed at three points after August of 2005, when the storm hit the U.S. Gulf Coast. Although rates of post-traumatic stress symptoms declined over time among the women, 1 in 6 still had symptoms 12 years after the hurricane, researchers reported in 2019 in *Social Science & Medicine*. Mothers with young children who were evacuees after the Chernobyl disaster and Chernobyl cleanup workers have had long-lasting mental health consequences.

Despite the potential impacts, only 35 percent of respondents in the study in *JAMA Network Open* reported that they had ever been offered mental health care to attend to issues that arose from the water disaster. If offered, most people—79 percent—took advantage.

The COVID-19 pandemic, another traumatic experience, hit the community while they were still dealing with the water disaster. In the most recent Community Health Needs Assessment for Flint and surrounding Genesee County, from 2022, 45 percent of respondents to the assessment's resident survey indicated that they were dealing with stress, and 33 percent said they had mental health problems such as depression or anxiety.

Helping and healing

Having too few mental health care practitioners is not an issue unique to Flint. Nearly 166 million people in the United States, about half the population, live in areas with a shortage of mental health professionals. The COVID-19 pandemic has only exacerbated the problem.

Treatment options did recently expand somewhat in Flint. In May, local mental health services provider Genesee Health System opened a new outpatient clinic that serves uninsured county residents. The treatment facility is funded in part by a recently passed property tax increase to support mental health in the county.

Beyond that, Flint organizations are taking community-based approaches to help residents cope. The Flint ReCAST program, supported with a grant from the federal Substance Abuse and Mental Health Services Administration, funds local organizations seeking to address trauma and stress in the community. ReCAST has supported art, music and dance programs for

young people and an initiative to build mindfulness skills among the police and community members.

ReCAST also funds Genesee Health System to offer free community mental health and resiliency trainings, on topics ranging from recognizing suicidal ideation to learning about mental health and stigma to building resiliency. ReCAST and Genesee mental health professionals have teamed up for virtual conversations about mental health called Talk About It Tuesdays.

The Flint Public Health Youth Academy, which Key began developing in 2014, is a homegrown initiative to inspire Flint's young people to pursue careers in public health. "I wanted to create a youth group that did not allow the water crisis to be a sentence of doom and gloom," he says, but rather a jumping-off point to create the next generation of public health professionals. Among the academy's activities is an annual summer camp that centers on a public health topic, such as environmental justice.

Looking to the future, Stevenson, the project manager for ReCAST, is interested in bringing training of mental health ambassadors to Flint. The idea is to train trusted community members to be a source of mental health information for their neighborhoods. Stevenson is also a big proponent of healing circles as a way to help people heal and build resilience.

People sing together at a community celebration on January 20, 2020, Martin Luther King Jr. Day, at the Flint Institute of Arts.

The Flint Farmers' Market, which dates back to the early 1900s, is a popular community spot in downtown Flint. Here, Joe Snider plays the cello outside of the market in October.

At the close of one healing circle on that Saturday in May, Todd Womack took out a skein of moss green yarn. Womack asked the participants to be ready to share something they appreciate about themselves. Womack went first, then tossed the skein to another participant while holding on to a piece of the yarn. As each person took a turn, the skein zigzagged across the space, unwinding along the way. In the end, everyone in the circle was holding on to the web of yarn, a physical reminder of the community and connections created that morning.

That afternoon, three different groups formed to discuss changes residents would like to see in Flint. People responded on sticky notes to different questions, such as what Flint would look like without gun violence. People talked about the city's history, GM's layoffs and the abandoned homes that still dot many neighborhoods, the result of years of population loss. After a peak of nearly 197,000 in 1960, the latest population estimate, from 2022, is under 80,000.

The people gathered that Saturday are among those who have stayed. They are Flintstones, as residents call themselves. While brainstorming about Flint's future, playful chants broke out between the groups, each of which had taken on a Flint-related name. "Flintstones!" one group cried. "810!" another responded, referring to the local area code. "Bedrock!" boomed the third, naming the town from the old *The Flintstones* cartoon.

When residents reflect on Flint, the strong sense of community comes up again and again. It's how residents have stood up for their health and safety during a disaster, and it's how they continue to care for each other.

"There's really this unity and connectedness with anyone who has lived here," Todd Womack says.

"We're a loving city," Dionna Brown says, "and we're going to be OK."

"There are amazing, deeply committed people that live here … there's a lot of commitment, there's a lot of passion," Lynn Williams says. "And that's why we stay." ■

Explore more

- Peter J. Hammer. "The Flint water crisis, the Karegnondi Water Authority and strategic-structural racism." *Critical Sociology*. January 2019.

FROM TOP: SARAHBETH MANEY/*THE FLINT JOURNAL*-MLIVE.COM/ASSOCIATED PRESS; JENIFER VELOSO

LOOKING BEYOND

Society for Science is thrilled to share our latest Annual Report. After celebrating our centennial in 2021, the theme of the 2022 report is "Looking Beyond," as we embark on the next chapter of our organization's history. It is also a nod to the excitement of moving past the worst days of the COVID-19 pandemic and an acknowledgement of the groundbreaking scientific advancements that defined the year, including discoveries made by the James Webb Space Telescope (a photo of the Carina Nebula, above).

Read about our STEM competitions, including the new title sponsorship for our middle school competition. Learn about our outreach and equity programs, which have supported teachers, learners and STEM-based organizations in the United States and internationally. And, of course, look back at highlights of Science News' wide-ranging coverage, as well as the debut of Science News Explores, a new print magazine that encourages young people and their families to follow their curiosity.

View the 2022 Annual Report: www.societyforscience.org/2022annualreport

SOCIETY FOR SCIENCE

On April 8, 2024, a total solar eclipse will be visible over North America (green marks the center of the eclipse path; blue and red mark the outer edges).

EXPERIENCES

How citizen scientists can help during the 2024 total solar eclipse

Next year, on April 8, a total solar eclipse will cross North America. It will pass over Mexico and cross 14 U.S. states, from Texas to Maine, before exiting over eastern Canada. This will be a particularly special eclipse.

The sun will be nearing its most active phase, its solar maximum, which comes around every 11 years. There will be an uptick in sunspots, increased light and radiation, and frequent blasts of charged particles from the sun's surface. These solar storms can threaten satellites and even disrupt communications and power grids on Earth (SN: 2/27/21, *p.* 16).

The combination of high solar activity and a total eclipse will provide astronomers with a rare view of the outer edges of the sun at a time when researchers have more scientific instruments to study the sun than ever before, says astrophysicist Kelly Korreck of NASA Headquarters in Washington, D.C.

But to take full advantage of this opportunity, researchers need as many sun watchers as possible. Here are a few projects looking for citizen scientists. —*James R. Riordon*

SunSketcher

AIM: Nail down the sun's shape

HOW TO HELP: With just a smartphone camera, this app asks volunteers to help time the appearance of bright spots of light, known as Baily's beads, that appear when sunlight shines through valleys on the moon just before and after the total eclipse.

"By including as many phones as possible, spread out over the 2,000-mile-long, 100-mile-wide path of the April 2024 eclipse, we will get views of the solar shape from a very large number of vantage points," says astrophysicist Gordon Emslie of Western Kentucky University in Bowling Green.

The results, Emslie says, will help researchers test theories of gravity by looking at how the shape of the sun affects the orbits of planets.

Gathering data won't interrupt any other eclipse-watching activities. Just prop up your phone to face the sun and start running the app at least five minutes before totality. The app will handle the rest, and you get to keep copies of the pictures as a souvenir. Find more information at sunsketcher.org

Dynamic Eclipse Broadcast Initiative & Citizen Continental-America Telescope Eclipse

AIM: Scrutinize the sun's corona

HOW TO HELP: Some eclipse projects will rely on teams of volunteers sharing specialized equipment for observations. The Dynamic Eclipse Broadcast Initiative will provide cameras and telescope systems, along with training, for over 40 teams who will estimate the speed and acceleration of plumes ejected from the corona, the outermost portion of the sun's atmosphere. The corona is of particular interest to solar scientists: One of the biggest unsolved mysteries about the sun is why the corona can be millions of degrees Celsius hotter than the sun's surface.

Meanwhile, the Citizen Continental-America Telescope Eclipse project will outfit upward of 35 teams with cameras that can record the corona with polarized light in a quest to understand how the solar wind emerges from the sun. Studying this steady stream of solar particles could lead to a better understanding of solar storms.

Both projects have limited supplies of equipment, which means limited opportunities for volunteers, so get in touch with them soon if you want to join, at debinitiative.org and eclipse.boulder.swri.edu

Eclipse Soundscapes

AIM: Listen to how an eclipse affects wildlife

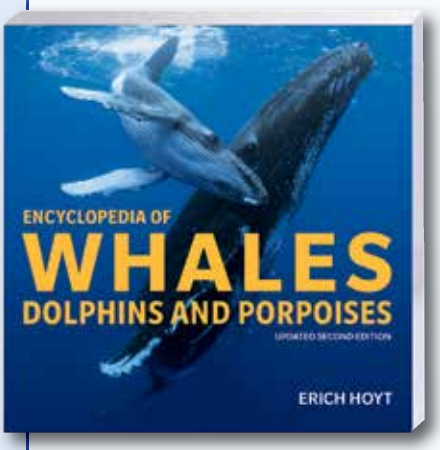
HOW TO HELP: This effort will re-create a 1932 project that asked the public to observe wild animals during a total solar eclipse. In this update, citizen scientists will have much more sophisticated tools to document how eclipses alter the behavior of insects, birds, mammals and other critters.

Instructions for preparing a sound-recording kit are available on the project's website, or sign up by January 16 for a free kit. Recorders will need to run from two days before the eclipse until two days after. Once observations are uploaded, volunteers can get training to analyze data. To see all the ways to participate, visit eclipsesoundscapes.org ■

NATIONAL SOLAR OBSERVATORY/AURA AND NSF

New books that help us see the wildlife around us

Two books by ocean researcher/protector Erich Hoyt



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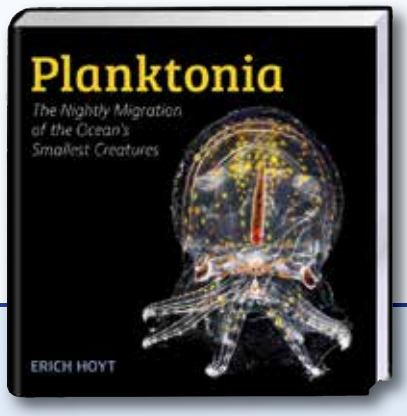

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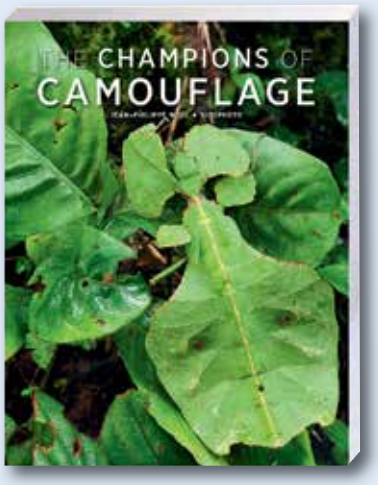

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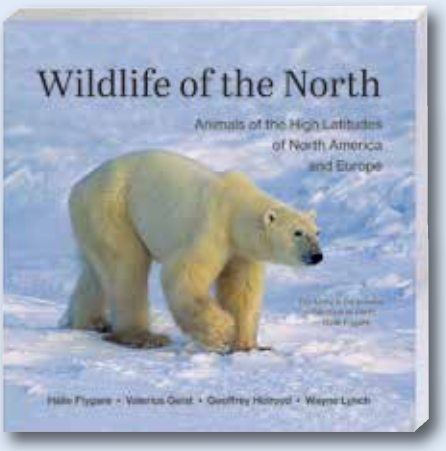

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Rethinking healing

Western colonists' seizure of Indigenous lands and subsequent abusive assimilation efforts continue to harm and traumatize Indigenous people, leading to high rates of mental illness, chronic disease, incarceration and suicide. Psychologists are researching whether mental health programs founded on Indigenous traditions can help these communities reconnect with their culture and heal, ***Sujata Gupta*** *reported in "Culture aids Indigenous mental health" (*SN: 9/23/23, p. 14*).*

The story resonated with reader **Gary Seeman**. "I retired from psychological practice not long ago and was rooted in [Carl] Jung's analytical psychology and Buddhist and Indian spiritual practices. All of those approaches helped me with clients and provided the depth needed for my own personal healing."

Mental health programs founded on Indigenous cultural practices, such as welcoming spirituality and a heartfelt connection to the land, can only help Indigenous people, **Seeman** continued. "Encouraging such profound wholeness may be what is required to start to progress against the horrendous intergenerational trauma that Indigenous peoples have suffered. What you're describing goes beyond the whole person to include the whole planet, something the rest of us must learn if we are to avert even more catastrophe."

Discussing depression

Deep brain stimulation, a technology that pulses electricity into the brain, is providing relief to some patients with severe depression, ***Laura Sanders*** *reported in "Lifting depression with brain implants" (*SN: 9/23/23, p. 16*).*

"Thank you for reporting on deep brain stimulation with such compassion for patients and families," reader **Kevin Cole** wrote. "I particularly appreciated your nuanced discussion of stigma." Many people with severe depression and other mental illnesses, including one of **Cole's** family members, experience stigma and other roadblocks in their daily lives.

Reader **Ellen Leff** appreciated **Sanders'** thorough coverage. "The in-depth report of patients' personal experiences in the article and the online videos brought much depth and perspective to the topic."

Watch these videos on our website at bit.ly/SN_DeepBrain

Make some noise

A platform made of clay, sand, ash guano and other materials discovered in the Andes may have been used by the ancient Chocorvos people to worship a thunder god. Dancing and stomping on the platform would have produced a thunderous boom, ***Bruce Bower*** *reported in "Ancient platform drummed up thunder" (*SN: 9/23/23, p. 13*).*

Reader **Lynn Allen** found the article fascinating and was reminded of the way valleys can sometimes funnel and carry sound over vast distances. "I live in New Mexico on a hilltop and enjoy hearing clear conversations from across the hill and other sounds that travel clearly and far," **Allen** wrote.

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A peek inside a rat's eye

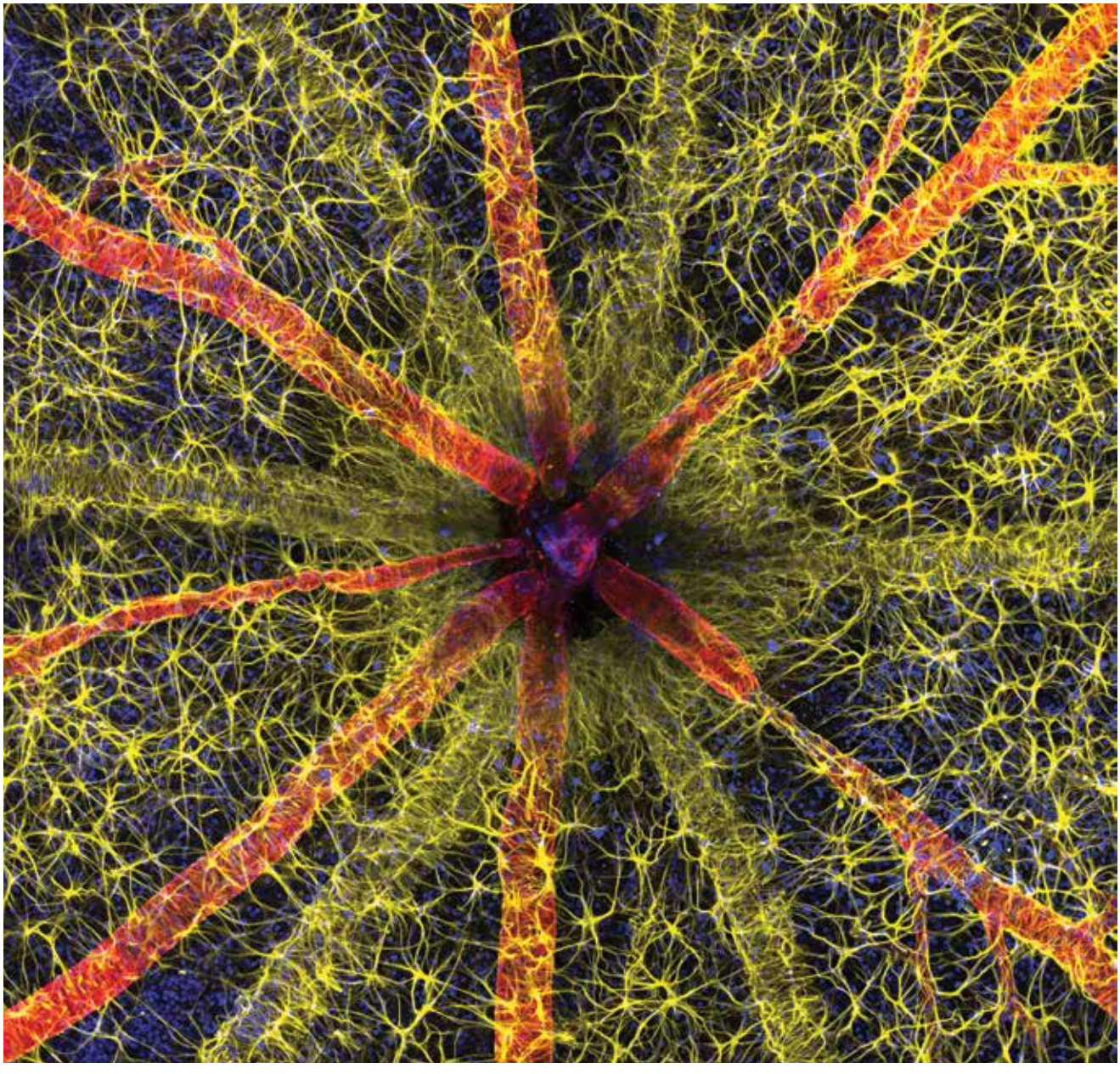
An eye full of cellular stars is a stunning example of the beauty that exists in nature's smallest sizes.

A glimpse of the back of a rat's eye, and the immune cells that keep it healthy, won first place in the 2023 Nikon Small World photomicrography competition. The image, composed of multiple snapshots captured with a confocal microscope, was taken by neuroscientist Hassanain Qambari of the Centre for Ophthalmology and Visual Science in Perth, Australia.

The photo (below) is artificially colored to showcase the eye's optic nerve — the black spot in the center — as well as surrounding structures in the retina, a layer of cells within the eye that captures light. A protein that helps blood vessels contract is shown in red, and cell nuclei are blue. In yellow are astrocytes, star-shaped specialized cells that help maintain a healthy environment for neurons.

The image is part of work that aims to uncover how diabetic retinopathy — a disease in which high blood sugar damages retinal blood vessels — can alter the function and structure of the retina, Qambari says. By the time people are diagnosed, the disease is typically already in a late stage and the retina has sustained irreversible damage. Some people can go blind.

By pinpointing any changes that happen early on, researchers may be able to develop a drug to reverse those changes before the disease advances and causes permanent damage. The photo is one of 86 recognized in this year's competition, the winners of which were announced October 17. — *Erin Garcia de Jesús*



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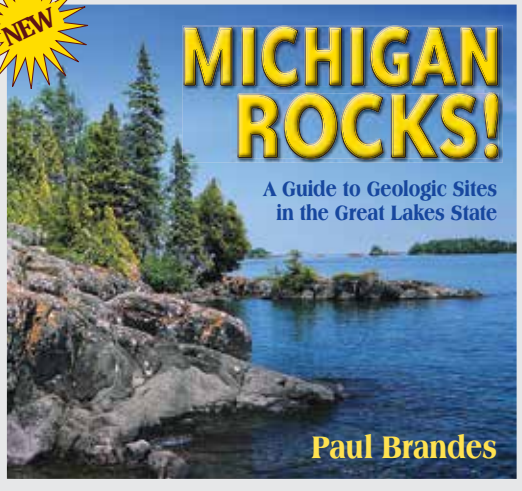

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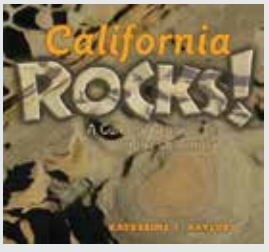

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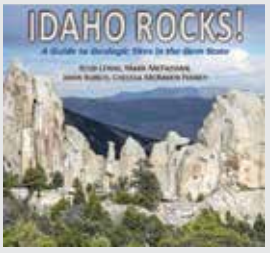

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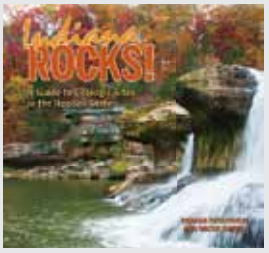

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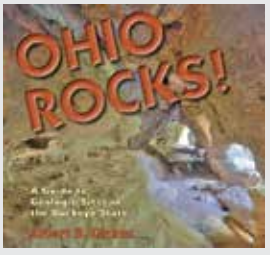

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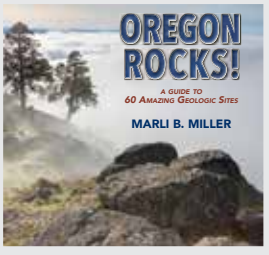

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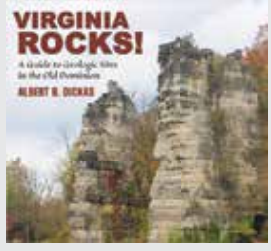

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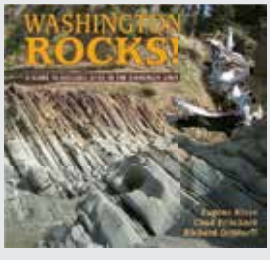

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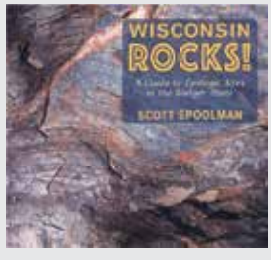

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